# DOCUMENT RESUME

| | | |
|---|---|---|
| ED 250 181 | | SE 045 158 |

| | |
|---|---|
| TITLE | Integrated Science Education Worldwide. International Conference (Nijmegen, Netherlands, March 28-April 7, 1978). |
| INSTITUTION | International Council of Associations for Science Education. |
| PUB DATE | Oct 78 |
| NOTE | 129p. |
| PUB TYPE | Reports - Descriptive (141) -- Collected Works - Conference Proceedings (021) |
| EDRS PRICE | MF01/PC06 Plus Postage. |
| DESCRIPTORS | *Curriculum Development; Educational Objectives; *Educational Trends; Elementary Secondary Education; Environmental Education; Higher Education; *Integrated Curriculum; *Science Curriculum; *Science Education; Science Education History; Science Instruction; *Teacher Education; Teaching Methods; Unified Studies Curriculum |

ABSTRACT

This document contains the full texts of plenary lectures presented at a conference which focused on developments in integrated science education (ISE), between 1968 and 1978, and on issues and new trends in science education in the 1980s and 1990s. These lectures include: (1) "Interaction of Science and Society" (J. C. Terlouw); (2) "A Review of Integrated Science Education Worldwide" (Sheila Haggis and Philip Adey); (3) "The Case for Teaching Science as a Unity" (Victor Showalter); (4) "Reflections on the Implementation of Integrated Science Teaching" (F. James Rutherford); (5) "Environment as an Integrating Factor in Science Education" (Rais Ahmed); (6) "Where Have We Got To? Where Are We Going?" (Judith Reay); and (7) "Where Have We Got To And Where Are We Going?" (Charles Taylor). Also included are summaries of 10 conference working groups. These groups concentrated on: the aims and objectives of ISE; design and content of ISE courses; education of teachers for integrated science; strategies and implementation of ISE; evaluation of ISE; resources for ISE; integrated science and environmental education, nutrition, health, and technical education; relationship of ISE to other subjects in the curriculum; national and international problems in disseminating and implementing ISE; and science and society. (JN)

***********************************************************************
*    Reproductions supplied by EDRS are the best that can be made    *
*                    from the original document.                    *
***********************************************************************

ED250181

U.S. DEPARTMENT OF EDUCATION
NATIONAL INSTITUTE OF EDUCATION
EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)
✓ This document has been reproduced as received from the person or organization originating it.
Minor changes have been made to improve reproduction quality.
● Points of view or opinions stated in this document do not necessarily represent official NIE position or policy.

ICASE

# INTEGRATED SCIENCE EDUCATION WORLDWIDE

## International Conference
## Nijmegen, Netherlands

28 March – 7 April 1978

"PERMISSION TO REPRODUCE THIS MATERIAL HAS BEEN GRANTED BY
Dennis G. Chisman
TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

SE045158

INTEGRATED SCIENCE EDUCATION
WORLDWIDE

# International Conference
## Nijmegen, Netherlands

28 March – 7 April 1978

# CONTENTS

page

Chapter 1: Introduction iv

Chapter 2: Plenary Lectures 1
2.1 Interaction of Science and Society, by Dr J C Terlouw 1
2.2 A Review of Integrated Science Education Worldwide, by P S Adey and Sheila Haggis 10
2.3 The Case for Teaching Science as a Unity, by Dr V Showalter 29
2.4 Reflections on the Implementation of Integrated Science Education, by Dr J Rutherford 42
2.5 The Environment as an Integrating Factor in Science Education, by Dr Rais Ahmed 53
2.6 Where have we got to? Where are we going? by Judith Reay and Professor C Taylor 58

Chapter 3: Reports of Working Groups 69
Working Group 1 69
Working Group 2 70
Working Group 3 75
Working Group 4a 78
Working Group 4b 82
Working Group 4c 83
Working Group 5 84
Working Group 6 86
Working Group 7a 90
Working Group 7b 93
Working Group 7c 96
Working Group 8 99
Working Group 9a 99
Working Group 9b 102
Working Group 10 107

Chapter 4: Papers submitted to Working Groups, Poster Sessions and Exhibitions 109

Chapter 5: Evaluation of the Conference 115

Chapter 6: Summary of programme 117

Chapter 7: List of Participants 118

## International Organising Committee

| | |
|---|---|
| Dennis G Chisman | Chairman |
| B G Pitre | President ICASE |
| J David Lockard | Past President ICASE |
| Brian G Atwood | Vice President ICASE |
| Victor Showalter | ICASE Executive Committee |
| Jan Vaernewijck | ICASE European Representative |
| John L Lewis | ICSU - CTS |
| Mrs Sheila Haggis | UNESCO |
| Wop IJ Zandstra | President NVON |
| Frits Th H Dekkers | Chairman National Committee |
| Chris J M Aarts | Director Faculty of Science |
| Mrs Marg M Smit | University of Nijmegen |
| Ms Sheila Hopkinson | Administrative Officer, ICASE |

## National Organising Committee

| | |
|---|---|
| Frits Th H Dekkers | Chairman |
| Albert Holman | Secretary |
| Charles F W van de Ven | Treasurer |
| Gerrit Verkerk | |
| Peter J M Toll | |

## Local responsibilities

| | |
|---|---|
| Educational Visits | Albert Holman |
| Exhibitions | Charles F W van de Ven |
| Integrated Daily | Jac van Trommel |
| Ladies Programme | Mrs C J Justa Markering |
| Local Arrangements | Peter J M Toll |
| Poster Sessions | Charles F W van de Ven |
| Programme Booklet | Mrs Marg M Smit |
| Social Programme | Gerrit Verkerk |
| | Ton G P Wiewel |
| NVON Congress | Louk G M Fennis |

## Sponsorship

Educaboek B V
Evans Brothers Ltd
Griffin & George Ltd
Heinemann Educational Books Ltd
Honeywell Bull (Nederland B V)
IBM Nederland N V
ICI Schools Liaison
John Murray Ltd
KLM Royal Dutch Airlines
Longman Group Ltd
Macmillan Education Ltd
Oxford University Press
Philip Harris Ltd
N V Philips' Gloeilampenfabrieken
Shell Nederland B V
Wolters-Noordhoff B V

# CHAPTER 1: Introduction

The 1978 Nijmegen Conference on Integrated Science Education will be remembered by the 270 participants (from 65 countries) as professionally stimulating - of course - but most importantly as an exceptionally well-organised event by the enthusiastic and generous Dutch committee.

The conference was held in the Faculty of Science of the University of Nijmegen whose professional, administrative, secretarial and general staff (including the restaurant staff) contributed so much to the success of the meeting.

The main aim of the conference was to take stock of the developments in integrated science education over the last 10 years and provide an opportunity to look forward to new trends in science education in the 1980s and 1990s.

The main thrust of this conference was on working groups in which all participants were involved. These groups provided the forum for exchanges of experiences and for presentation of views on a wide variety of specific topics.

Although many countries have been involved in aspects of integrated, unified, undifferentiated or general science for many years, from an international point of view 1968 marked the first occasion for assessing objectives, suggesting definitions and planning projects. This was at the Varna (Bulgaria) Conference. In 1973, at Maryland USA, there was a major meeting on the education of teachers for integrated science. Now, in 1978, we had this opportunity of looking back and looking forward, of assessing successes and failures, and of planning new avenues for development.

The conference was organised and supported by:

- The International Council of Associations for Science Education (ICASE)
- The International Council of Scientific Unions (ICSU)
- The United Nations Educational Scientific and Cultural Organisation (UNESCO)
- The Association for Science Education in The Netherlands (NVON)
- Faculty of Science, University of Nijmegen, The Netherlands
- The British Council, United Kingdom
- Ministry of Education, The Netherlands
- Ministry of Foreign Affairs, The Netherlands.

This small publication carrying the full texts of the plenary lectures, summaries of the working group discussions and a list of papers submitted to the groups and the poster sessions will, it is hoped, provide a useful reference to the conference for those who attended and a guide to the plenary lectures for others. There is also a list of names and addresses of participants so that hopefully communication among them will continue and that science educators who would like copies of papers listed may be able to write directly to the authors concerned.

The full proceedings of the working groups - the commissioned papers, edited and supplemented by the authors as a result of the deliberations at Nijmegen - will appear later in the UNESCO New Trends in Integrated Science Teaching (Volume V) - editor: Miss Judith Reay.

As Chairman of the conference I would wish to express my sincere thanks to the chairmen of sessions, to the rapporteurs, authors, lecturers, evaluators and editors for their magnificent support. Particularly I would thank the local committee and the organisers in Nijmegen. The names of those responsible are appended together with the names of organisations, in addition to the sponsors, who contributed to the meeting with grants and in other ways. Finally the largest thanks must go to the individual participants many of whom travelled great distances often at considerable personal expense to take part in the 1978 Nijmegen conference.

Dennis G Chisman
Chairman

October 1978

# CHAPTER 2: Plenary Lectures

## 2.1 Interaction of Science and Society

Dr J C Terlouw, Member of the Netherlands Parliament

The history of man is interesting and varied. Civilisations have come and gone. Some were quite isolated, others strongly influenced one another. There is a great difference between the influence of the Chinese and Greek cultures on for instance the Middle Ages. A number of known and a multitude of unknown factors have given the world its present aspect. Socrates and Aristotle, Pythagoras and Euclid, but also the caravan routes through Samarkand and Tashkent, the destruction of Jerusalem, the cynicism of Petronius, the combination of piety and cruelty in Philip II, the myriad diversity of people and events have made the history of man an inexhaustible source of study and speculation.

Influences of every kind. Yet I am prepared to assert that nothing in the world has had such a fundamental, such an irreversible and such a rapidly expanding influence as the development of the physical sciences. Christianity and Islam also had a profound effect on the world, but their sphere of influence was more limited geographically and took a much longer time. The fact remains that the physical sciences and the related technical sciences have completely changed the face of the whole world (not only the culture of the white population) in a few hundred years. They exercise a profound and often catastrophic influence on almost all existing cultures, and, according to many, they are even an immediate threat to the survival of the human species, either through nuclear weapons or through ecological disturbance.

It seems as if the development of Science and Technology is an autonomous process - that it has developed within itself. In my opinion this is only superficially true. Behind every development there is a decision, behind every decision a person or a group of persons, and behind every person an interest. This interest can be the motive for keeping the decision secret and creating the impression that events have taken place independently.

Therefore interaction of Science and Society has everything to do with decision-making processes. It is a matter of master or servant. Science and Technology should of course be the servant of man, but through unsound decision-making it is often the master, inspiring fear because of its arbitrariness.

In the second place we are not sufficiently aware of the powerful role played by Science and Technology. We are blinded by the prosperity, the unprecedented possibilities and the rapid changes which Science and Technology have brought us. We do not wish to be ungrateful to the beneficent source of so much comfort or scope for self-realisation. We should not look a gift horse in the mouth. A critical attitude towards the provider of so much good seems almost improper.

Yet there is reason enough for such a critical attitude. People are realising this more and more. Increasingly often the topic Interaction of Science and Society is being discussed, in particular by those associations devoted to Science and Technology.

## Man's dependence on technology

Man is strongly dependent on technology. Of course man and technology are fundamentally interconnected, but man seems to have become the slave of his own ability.

Let us have a look at food supplies. The number of specimens of a species does not depend on potency, but on the availability of food. This also holds good for Man. Consequently we see that the rate at which population doubles is clearly connected with the development of agricultural production. In the distant past the domestication of animals made it possible for food supplies to increase and consequently the number of people. After the Middle Ages a radical change in environmental planning policies (including the discovery of new continents and emigration to them) had the same effect. Even the introduction of the staple of the Dutch meal, the potato, contributed its share. Perhaps out of partiality for this vegetable, the Dutch population increased more than that of any other people. Be that as it may, the time for the population to double diminished from more than 1000 years to 200 years.

That was nothing. When Science and Technology really started to get involved, only then did Homo Sapiens really start to evolve.

Around 1850 mineral fertilisation was introduced and 80 years later the population had redoubled. Especially after 1945 mechanisation in agriculture has increased enormously. Chemicals combat "weeds" and "vermin". Irrigation is applied on a large scale. The use of fertilisers has increased from approximately 8 million tonnes per year in 1940 to approximately 800 million tonnes per year in 1975. And in 45 years' time the world population doubled itself again.

Other scientific and technical developments in medicine and hygiene, the eradication of contagious diseases and the like, have resulted in such a population increase that agricultural production cannot keep up.

And there we have the dilemma: under penalty of even more starving people, even more little children with swollen bellies and emaciated faces, we are obliged to keep on using harmful agricultural methods and, indeed, use more of them.

Who dares to claim that in a starving world insecticides, pesticides and monocultures ought to be abolished? Who would dare have the masses perish that have been indirectly procreated by technology, via the seeds of a greater food production and better hygiene, by applying the definition of technology as given in an encyclopaedia as "manifestations through which man makes his existence more agreeable and resists everything that threatens his existence"? For it is obvious that the population explosion is the result of technological development and yet threatens human existence.

Another obvious example of how we have made ourselves dependent on technology is armament. The atom bomb was developed to fight fascism by confirmed anti-fascist physicists who knew very well what they were doing. (Hitler would probably have had the atom bomb sooner than the Americans if he had not driven out his Jewish Nobel Prize winners.)

Again, we can euphemistically say that the nuclear bomb is an acquisition with which man defends himself against that which threatens his existence. But of course, the reality is that, if anything threatens the existence of man, it is nuclear weapons. In 1945 a section of mankind resorted to the atom bomb to defeat fascism and in 1978 NATO feels dependent on these weapons for its freedom, but at the same time the whole of mankind feels a threat to its existence from these scientific/technological products. This is dictated by politics but before that there was the scientific dictate, which makes this development possible.

Technology is part of man but we have made ourselves too dependent on it. I sometimes wonder what would happen if during a severe winter the electricity supply (including the central heating) were to fail completely for a few days. Or if the Rhine were to be poisoned (which to a certain extent it already is) for a few weeks.

We know that with our methods of production we contaminate the environment, and in particular threaten oceanic life. Unfortunately, we can only tackle the problem very slowly because otherwise the economy will collapse. Especially in those areas where technology does not make life more agreeable for us, or the areas where science does not protect us from that which threatens our existence, but is a threat itself, it is difficult to hold back. Science and Technology do not like to be dictated to. They clearly resemble a magician's apprentice. We have become too dependent on them.

## The one-sidedness of science and technology

Science and Technology have commanded respect, among other things because they have concealed their own one-sidedness. We can see how a television picture is transmitted, without any interference, from continent to continent via satellite; we can be flown smoothly to New York in 6 hours in an air-conditioned cabin; we hear of atomic submarines sailing under the Polar ice; we see how printers of computers produce data at lightning speed, the calculation of which would have taken the human brain years. But we easily forget that the midge that was walking on the writing paper and was accidentally crushed by the pen, cannot possibly be brought to life again by even the cleverest scientists or the most proficient technicians, let alone that a new specimen be synthesised.

Our knowledge is great but one-sided. As regards organisms we have only just started to form an idea of the simplest ones: we cannot even reproduce the transformations that take place in every green leaf.

But meanwhile, we know quite a lot about the laws of inanimate nature, we know about materials and know how to use them, we land on the Moon and everybody can watch it on his colour television.

We know precious little either about processes in human society. We cannot prevent wars breaking out, we do not know what to do about unemployment, but we can put everyone into a computer information system and by pressing a button find out who is Roman Catholic or who was.

In some fields technology has achieved miracles. We pile up one technique on another so that the structure does not collapse, but reaches up to heaven. In this way technical development has brought us prosperity, comfort, bread and circuses. The importance of this is greatly overrated and the disadvantage is that people often forget that technology is limited, one-sided in its achievements.

## The influence of science and technology on ethics

Science and Technology strongly influence our ethics. Our attitude towards sex has changed. Compared to 20 years ago we think differently about what is and is not acceptable. Whatever your opinion, it is bound to have something to do with the Pill, the coil, voluntary sterilisation and what have you.

Religious life, at any rate its form, has changed and probably also its substance. I think it very likely that this has to do with technological developments. Visits to the Moon, watched everywhere, reduced the infinite heaven to a human level. The popularisation of flying brought other cultures and other religions within everyone's field of view. Television brought cynicism, the relativity of things, the ridiculing of values hitherto considered to be unalterable, into everybody's living-room. In itself we do not need to be too negative about the fact that technical developments broaden one's horizon and consequently stimulate ethical developments. As long as we are aware of this.

In the past people took much pleasure, even without the Pill, in doing things which the Pill has made less risky nowadays. To my mind there is a "law of conservation of faith" whereby faith abandoning the church re-emerges elsewhere. Therefore I do not hold the view that ethical devleopments are dictated to by scientific developments, as a long-term dictatorship can, but they do have a strong influence.

As an individual, as a people and as a species, man undergoes all kinds of influences. The birth of his child, a big catastrophe or the invention of the semi-conductor do not pass unnoticed by the individual nor by society as a whole - fortunately not, because development is part of life. Therefore it is in itself not really to be wondered at, and not so objectionable, that the development of technology influences the ethics of people. The question is whether we are aware of it and whether we can, if required, break away from it.

In theory everybody admits that man should be central and not science, but what is then the essence of man, what is the fundamental thing that is not to be touched? If one out of every twenty office workers cannot bear working in an air-conditioned room without any contact with the open air, should this then be a reason to install adjustable windows and not blinds that close automatically when the first ray of sunshine appears? Or should this man have become a lumberjack instead?

Has a human being the fundamental right to see trees, to observe the changing of the seasons, to see the trees coming into bud, to see the leaves falling? If so, where do all these monstrous blocks of flats come from?

Is it essential to man that he wants to be near to other people, that he is looking for company, and needs contact? If so, how has it come about then that we have arranged our organisation and production in such a way that as a member of society we are entangled in thousands of incomprehensible regulations and as an individual have become so independent, with our refrigerator, car and hospital facilities, that many people become lonely behind their automatically operated doors?

When I was doing my military service, I rented a room from an old lady and her fifty year old daughter. The old lady was physically weak, but sound in mind and she had reconciled herself to the fact that her end was near. One Friday, when I was leaving for the weekend I said goodbye to her. The daughter who was showing me out. said very calmly that her mother only had one more day left to live.

When I returned on Monday the curtains were in fact drawn, but the daughter who had previously been so calm was now confused and irate. They had come for her mother that Saturday and had taken her away from her dark room with the clock and faded armchairs and taken her to a bright hospital room looking out on to a new housing estate. There she had died in a high bed twenty four hours later than expected with tubes in her nose and arms.

That is the way it goes in a society where Science and Technology do influence the development of things, but have hardly any influence on the decision-making process. One sometimes wonders whether the human being is the measure of all things in this technocracy.

## Decision-making in society

The decision-making procedures in society are inadequate and this results in a kind of technological overflow swamping people, which is not quite the way people want it and which nobody seems to be able to change.

This happens in spite of the fact that experts are a characteristic phenomenon of our industrial society: we have far too many experts. Who can call himself an expert when it concerns the making of policy decisions, the effects of which will be especially felt in ten years' time? Who can consider himself an expert when it is a matter of whether people are going to feel happier or unhappier on account of a certain decision?

Being an expert is a tricky business. Before you know where you are you find yourself using your expertise to keep the system intact, within which this expertise is applicable. The system consists of lines of power, administrators, advisers, experts, regulations, laws and what have you.

But it is not the system we are concerned with. The system is an instrument, not an end in itself. In the years after the war we energetically started restoring and perfecting our technocracy. And in the sixties the quality had risen greatly.

There was an almost perfect system for taking care of Old Age Pensioners, living until their death in neat little rooms with a communal room containing a television set.

There was an almost perfect system of privately-owned flats in tidy blocks of sixty or one hundred and sixty, with balconies on which you can put a pram in sunny weather and nicely-planned strips of green between the blocks. The partition walls were somewhat thin and the power of the amplifiers increased, but one gets used to it.

Workers' productivity increased steadily, which was translated into guilders with which to buy cars and into longer holidays, enabling people to go on package tours to Mallorca. But no heed was paid to the slight drawback that, rather suddenly, it was no longer possible to swim in open water, hardly anywhere in Holland.

In perfecting technocracy one aspect was scarcely taken into account, namely whether people - the clients of the system - really wanted things this way.

But surely these were democratic decisions you may argue. Certainly, but democratic systems - even a democratic system as we have it in Holland, just about the least evil in the world - can function in a way which has very little to do with the demands of its citizens. Casting your vote once every four years hardly guarantees that things you would like to see done are in fact carried out.

Proof for this theory is the coming into existence of pressure groups. In the sixties people got together who said: in this perfect technocracy there is alienation - in the best of all worlds there is fossilisation - in this splendid democracy there is pollution. And they got together to save a tree or a wood, a brook or an estuary, a façade or a church.

The pressure groups seemed to think that Science and Technology, embodied in the experts, were more interested in a specific kind of development in society than in decision-making. Machines were becoming more powerful and more complicated, organisation was becoming more and more impenetrable, the human being was becoming less important, the system was developing itself.

Without wanting to idealise pressure groups I think we must conclude that pressure groups are more aware of the need to achieve a real decision-making process than either politicians or Scientific and Technological organisations are.

We should not be afraid of science and scientific developments. They are as human as thinking, speaking and breathing. Nor need we be afraid of organisation that has been pushed too far, as long as we bear in mind that all these developments exist for man and that man does not exist for these developments.

This means that the people, who are to undergo the consequences of measures, should always be consulted about the decision. This is not always the case, either on account of a wrong decision-making policy, or on account of incomplete or incomprehensible information. For these things affect the essence of man's being: his choice of freedom, his own free will.

Do I ever find myself faced with the choice of whether to follow my party's programme or my scientific conviction?

At one time I was an expert in the field of physics. For 13 years I carried out physical research and worked in various laboratories, some of them well-known foreign ones. Consequently, I am often expected to give an expert opinion on a problem intimately related to physics, as for instance the energy problem.

A complete illusion.

Physicists cannot even understand each other's publications, unless they have practically the same specialisations. How could you then have blind faith in the expert advice of a physicist when a problem concerns not only Joules and Watts but also population, environmental planning, consumption patterns, genetic effects and what have you?

A good decision complies with the condition that first the facts are gathered, that all relevant arguments have been presented clearly and distinctly and that then, having heard and understood the pertinent facts and arguments, the political decision is made based on conviction, vision and starting-point.

My training as a physical scientist helps me to gather the facts, to understand these facts, perhaps also to present the relevant arguments clearly and distinctly. Such a training may help people to be objective, to think logically and to be reasonable. It may help to distinguish between false and true arguments, to solve paradoxes. But in the end this training will not be of any use when political decisions have to be taken, for they are based on convictions.

It is in the first place the politicians who are responsible for taking decisions and the development of society, but also practitioners of Science and Technology should not shirk their responsibility of recognising tendencies and fighting them.

The classical example of a development where the scientist does or does not bear responsibility is the construction of the atom bomb and the hydrogen bomb. But then this case is relatively simple. It was Truman who decided that the bomb was to be dropped on Nagasaki and two days later on Hiroshima, but if these bombs had not existed he would not, of course, have been able to take such a decision.

Without a shadow of doubt, the scientists knew what they were doing when they were making the atom bomb. Vanever Bush, director of the World War II Office of Scientific Research and Development, writes in his book 'Modern Arms and Free Men', 1949:

> "Before the second World War military laboratories were dominated by officers who clearly felt that the scientists and engineers working in these laboratories, represented a lower social caste ... For that matter, these officers had not the faintest notion of the effect science had on the development of technology and armament..."

In 1941 the very famous Office of Scientific Research and Development I just mentioned was founded. This laboratory was run by civilian scientists. Vanever Bush's creation worked for military aims, together with military personnel, but it was not controlled by the latter. Roosevelt consented to this organisation not carrying out army orders, but being a source for developments in the field of armament, without taking notice of whatever ideas technically ignorant military personnel might have about it.

Without expressing an opinion on whether the development of the atom bomb was desirable or not, I just want to say that it was developed by physicists and engineers who knew full well what they were doing and could not simply shift the responsibility on to the army or on to the politicians. And indeed this appears from what the Nobel Prize winner Compton wrote about his visit to Fermi in Rome in 1931:

> "How could we have dreamt that we would welcome him ten years later in Chicago, where he was to carry out nuclear research with us, the purpose being no less than maintaining safety and freedom in the world."

Science and Technology play a decisive role in industrial society and consequently scientists occupy key positions. Science and Technology for a great part determine the quality and the tempo of life and in doing so make mistakes. Thus those who practise Science and Technology bear great responsibility.

It is clear that we should no longer do everything we are capable of doing. It is necessary to have a more careful decision-making process, a more careful weighing of pros and cons than in the past as regards the question whether things which are technically possible should or may be practically applied. At the same time we should consult those for whom the application is intended and those who will undergo its drawbacks.

## Consequences for education

It is an illusion to think that a better decision-making process could be achieved if scientists are not themselves fully aware of its necessity, and do not cooperate, for the scientists themselves are equipped with the necessary knowledge, and no one else. Therefore awareness of the consequences of scientific research should be an essential part of their training.

But who is to teach the social consequences of research? Professor Van Melsen said recently:

> "The remarkable thing about science - and this is what gives it such a precarious position in culture and society - is that science does not have methods at its disposal enabling science to question itself ... The concept of science is not a scientific notion".

A human activity, such as practising science, cannot be described with the aid of that science. Something like sociology or philosophy or perhaps history is needed. And so the following question is relevant: not who is to teach science, but who is to teach science as a human and therefore social activity? Despite any possible objections, I still believe that the science teacher should do that for the following reasons.

Firstly, the teaching of the social consequences of science will inevitably remain superficial if the teacher has not thoroughly investigated the essence of science himself. In order to sound believable to the pupil, you have got to know what you are talking about.

Secondly, it is not right that many people should judge hard and soft subjects differently. Those interested in science often sneer at what they call the vagueness of the Social Sciences, whereas the pupils who are fascinated by these Social Sciences accuse their brothers and sisters, who have an aptitude for the Exact Sciences, of dryness, of being blinkered and of lack of emotion. It is advisable that this gap is not widened. We must learn to realise that there can be no question of true erudition in the case of somebody who is completely absorbed in mathematics and physical science, nor in the case of those who take no interest whatever in these subjects. We indeed have a case of narrow-mindedness on our hands if science teachers cannot or are not allowed to discuss the consequences of their subject with their pupils. If they cannot discuss these consequences, it is a case of narrow-mindedness on the part of the teacher; if they are not allowed to, those who draw up the rules are to blame.

On no account should the sober and scientific decision-making process be hindered. There is no harm in philosophy and sociology influencing the application of scientific research, but it must never influence the result of research. The most important aid to science, mathematics, developed much earlier than science itself. In antiquity mathematics had already achieved a high degree of sophistication. More than a thousand years were to pass before people dared to experiment. 'My mind is made up, don't confuse me with the facts.' Experiments shook age-old verities to their foundation. Philosophy and political ideas can be a serious hindrance to pure scientific research. Therefore studying and teaching the consequences of science should not be allowed to run the risk of conflicting with the results of science itself. That danger arises if the two are separated.

Taking everything into consideration, I come to the following conclusions:

1. It is no longer admissible to practise or to teach physical science without taking into consideration the profound consequences of science and technology for human society, for the world and for the future.

2. This aspect cannot be separated from the practice and teaching of science. It ought to be an integral part of it.

These conclusions naturally raise the question as to where the science teacher should obtain the knowledge and where should he find the motivation necessary to teach something that is not really part of the methodology of his subject. And the answer is that he will have to learn it himself first. Universities and other institutes of higher education will have to pay more attention to this.

It is expressly drummed into the heads of those studying to be a chemist which chemicals are poisonous, how to recognise them, how they work and how to use them to the benefit of the client of the medical system and not to his disadvantage. Why not do the same with the drawbacks of our technical attainments? Perhaps some people will hold it against me that I dare to compare the instruments of the welfare state to poisons, but then this is because we are not accustomed to thinking along such lines.

A series of great thinkers in the history of man have made the laws of nature discernible, a structure of incomparable beauty. Galileo, Newton, Maxwell, Planck, Einstein, Darwin, Linnaeus, Lavoisier, Dalton and all the others. It was a joy to study it myself and it is a joy to pass it on.

But the scientists themselves have up to now looked more to the beauty of the structure than to anything else. We ought to know better by now. In addition to greater prosperity, more scope for self-realisation and a (somewhat) longer life, science has also provided us with weapons that can kill on an incredibly large scale, even put at stake the existence of all that lives; production methods that pollute the oceans, use up raw materials, and turn the world into a rubbish-dump; agricultural methods which are just as inadmissible as the 'slash' and 'burn' techniques of our ancestors, but on a far more dangerous scale. These are obvious and well-known drawbacks. It should be possible to investigate to what extent science and technology are indirectly responsible for more people becoming lonely, contacts being lost, cultures becoming impoverished and materialism increasing.

I am not an opponent of science and technology, but the contrary. Technology is part of man just as a roof is part of a house. But science and technology should be reduced to their true proportions. Their influence is great, indeed enormous; at first especially on western cultures, but now on the whole world. And they only modestly contribute to human happiness. Or rather, they can contribute considerably to this, as long as we see to it that the one hand does not take away what the other one gives.

This relative aspect I would like to see incorporated in the teaching of science. This will take time, which will be at the expense of teaching the methodology of the subject itself. But some things are more important than the calculation of the mechanical heat-equivalent.

The laws of nature are immutable. If we take the line that the same also applies to human nature, we might as well give the whole thing up. For the way in which man has treated nature since he started to fathom its laws does not offer much hope.

But a different approach is also possible. We can try to bring about a change in mentality. When I say this in political forums I am obviously asked how we can do this. I invariably answer: through education.

Wherever knowledge increases, responsibility increases. He who teaches young people probably shapes the future more than anybody else. Certainly he who is aware of the problems and at the same time teaches young people, bears a very heavy responsibility.

## 2.2 A Review of Integrated Science Education Worldwide

Sheila Haggis, Division of Science, Technical & Vocational Education, UNESCO, Paris
Philip Adey, Centre for Science Education, Chelsea College, London

### Introduction

#### Our Aims

Let us say, first of all, what we think this paper should try to cover. A review such as this should, we think,

a. provide an overall picture of the state of integrated science education as it stands today, and

b. identify worldwide trends in the development of teaching and learning in integrated science.

Ideally it would have been useful to be able to quantify the data fully, but the difficulties of assessing levels of implementation of curricula proved formidable, and we cannot claim to have made much progress in this direction.

#### Sources

We have sought information about curricula from a variety of sources, most notably

- answers to questionnaires sent out by ICASE to all ICASE members, and to some non-members also;
- the International Clearinghouse Reports, especially the 9th and 10th reports;
- Unesco records;
- the British Council science education reference collection;
- the integrated science education library at Chelsea College CSE;
- personal knowledge and approaches to individuals.

To what extent this review is found to be helpful, its value depends to a very large extent on the efficiency of these sources of information, and the generous cooperation of all those to whom we turned for help. Had they and their resources not been available to us, the task would have been virtually impossible to complete.

Altogether we have collected data on some 130 courses and projects. If this does not include every integrated science project in the world, we are at least confident that we have obtained a representative sample from which conclusions about the nature of integrated science education today may properly be drawn. At the same time, we would be grateful to receive details of any integrated science curriculum that is not represented in any of the sources noted above, so that we can ensure its mention in the next Clearinghouse Report.

## What is included

For the purpose of this paper it is necessary to be clear about the term "integrated science education". Many definitions of integrated science have been proposed, but we decided to make use of the Integration Matrix proposed by Abraham Blum (1973) as a criterion for including or excluding a particular course from this review. Blum's matrix has two axes: scope and intensity. The scope of a course is the range of disciplines, scientific and otherwise, which it includes, while the intensity axis measures the extent to which subjects have been blended, and a deliberate synthesis made of the material.

We have chosen to review only courses which have a substantial amount of both "scope" and "intensity" of integration. Thus we include only courses in which at least two scientific disciplines are involved, and where, in our opinion, a substantial amount of interweaving of these disciplines has taken place. For instance, the Course of Coordinated Science developed for secondary schools at the University of Palermo in Italy is included in our data bank, since it involves a genuine integration of chemistry and physics. On the other hand, a project such as Initiation aux Sciences et Techniques, of the University of Paris, is not included in our review. Although this project uses both chemical and physical ideas, the chemistry is presented as a discrete unit, provided as a service discipline to the physics whose renovation in secondary schools is the main purpose of the course.

We were also concerned about the problem of defining "curriculum". Our main criteria for inclusion here were some evidence of (a) publication, or intention to publish, and (b) trials of material before publication. Thus a school's own curriculum plan, devised for use in that school only with no thought of use outside, would be excluded by criterian (a). A textbook written and published simply as a commercial venture, with no development or implementation programme to support it, would be excluded by criterion (b).

The position we have adopted with regard to defining "integrated science education" and "curriculum" does not imply any value judgement on the courses which are included or excluded from consideration. Not does it imply that courses which we have excluded could not, on other criteria, be regarded [illegible] integrated science curricula. It is simply the way that we have chosen to sort out the large amount of material that has come to our attention.

## An Overview

### Classifying Curricula

Even within the limits we have chosen, there is an enormous variety of courses to be included. Clearly we cannot mention by name every one of the 100 curricula in our data bank, and if we tried to do so this paper would become no more than a tedious catalogue. In trying to attain our first aim - to provide an overview of the state of integrated science education today - it will be useful to consider some methods by which curricula may be classified. These methods of classification are not intended to provide hard and fast barriers between types of course. Rather, each classification should be seen as a spectrum of description along which every course will find a place, either at an extreme or at some intermediate point.

Each system of classification, or dimension, has been chosen on the basis of its potential usefulness. For every one we should be able to answer "yes" to the question "Does this classification give information about the curriculum that is useful to teachers or to education authorities?"

The dimensions of description that we have chosen are as follows:

- date of inception;
- age range for which the course is intended;
- ability range for which the course is intended;
- country or region of origin of the course;
- language;
- initiating authority;
- organization of the course;
- flexibility of the course;
- scope of integration;
- intensity of integration;
- printed material produced
- audio-visual material produced;
- laboratory facilities necessary.

Where possible, we have also tried to gather some information about the implementation of the course. This is a problem to which we return later, but for now let us examine in turn each of these descriptors, explain them more fully where necessary, and give examples to illustrate our use of each one.

Date of inception

The date of inception of a course is not in itself of any special interest, but taken collectively the birthdays of new courses can throw light on trends in integrated science education. We will return to this point later.

Age range

In our data bank we have used age as a rough guide to the educational level of the course. Rough, because in some countries there can be a wide age range of pupils at the same level in their progress through the educational system. Bearing this possibility in mind, we may distinguish five levels of education where integrated science may be appropriate.

a. Primary, approximately 5 - 11 years, or grades K - 7. Virtually all science curricula designed for this level are integrated. As examples of primary integrated science projects we can pick:

The Solomon Islands Primary Science Curriculum, started in 1971 by the Solomon Islands Ministry of Education, with UNESCO assistance. This curriculum is defined by a teachers' guide, and programmed units are provided for the pupils;

The Primary Science Project, Lebanon is one of the projects of the Centre for Educational Research and Development in Beirut;

Science: A Process Approach, from the AAAS in the United States was one of the first (1963) and now one of the largest integrated science projects of all.

(Please note that our selection of examples here and throughout this paper is a random one, and does not imply any sort of grading of curricula.)

b. Lower Secondary, approximately 12 - 15 years, or grades 7 - 9. This is the area in which the growth of integrated science seems most rapid. This may reflect the extended provision of secondary education in all countries, and also the acceptance by old established secondary schools of integrated science as a good foundation for scientific thinking, even where separate sciences are thought more appropriate at higher levels.

As examples we may cite the Scottish Integrated Science Curriculum, and the various programmes around the world which are derived from it; also the Secondary Science Project of Papua New Guinea which has recently introduced material for grades 9 and 10, while embarking on a revision of its grade 7 and 8 material started in 1971; and the Study of Environment in City and Suburbs of the University of Genoa in Italy which aims at the socialisation of urban students through an integrated study of their environment.

c. Senior Secondary, approximately 15 - 17 years, or grades 10 - 12. Integrated science courses at this level are sometimes offered as alternatives to separate science curricula. Generally, however, those who continue in full time education to the age of 17 or 18 are those few who have their sights set on further education. Since the traditional curricula provided for such pupils are often academic in outlook, the newer integrated science curricula for this level are sometimes put in the defensive position of having to prove themselves to be academically respectable. This can lead to the development of courses or syllabuses which make very high level demands on the pupils' levels of thinking. One thinks here of the Schools Council Integrated Science Project (SCISP) in England, and of the Caribbean Integrated Science Curriculum, (CISC).

In other educational systems, where it has become usual for the majority of pupils to remain at school at this level, integrated science for senior secondary students may be designed especially for those more interested in the humanities, or for the less able pupils. The Nuffield Working with Science is an example of the former, and the Schools Council City Scene Project, from Birmingham, England, an example of the latter.

Integrated science may also be seen as the most appropriate foundation for students at the senior secondary level who have a special career interest. The Biomedical Interdisciplinary Curriculum from California is one such course, aimed especially at high school seniors who have an interest in the health professions.

d. Teacher Education The growth of integrated science courses in schools has inspired the growth of projects designed to promote the teaching of integrated science. Integrated science may be used both in the education of specialist science teachers and with teachers of general subjects. Some examples are:

Analysis of the Evolution of a Science Concept, a course that uses original research papers concerning the concept of the macromolecule to introduce teachers both to scientific methods and to the social implications of scientific findings.

The Science Teacher Education Project (STEP) in the UK, and courses derived from it in Israel (HEME) and Australia (ASTEP) provide banks of resource material for the training of science teachers.

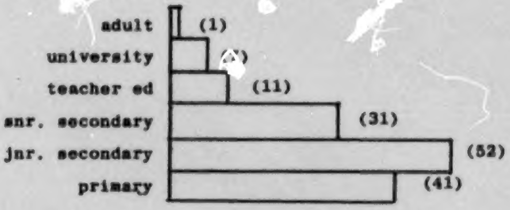
The UPE Teacher Education Project in Nigeria forms a vital part of the massive push towards Universal Primary Education in that country.

e. University Some of the integrated science courses for University students are designed for liberal arts majors to give them some understanding of the ways of thinking characteristic of scientists. An example from the United States is the Man and his Technology course devised by the Engineering Concepts Curriculum Project. Other university level courses such as the Open University's (UK) Science Foundation Course are intended to give students an overall view of science and to bring out the relationship between science and society before the students embark on courses in more specialized aspects of science.

f. Adult We only came across one curriculum specifically designed for adults, and that is the integrated science course developed by FUNBEC in Brazil for adults who have recently completed a literacy course.

The distribution of all of the courses we have perused amongst these levels is shown in figure 1. We suspect that since virtually all science taught at the primary level is integrated there may be a tendency for these to be under-reported. Even allowing for this, the prominent effort at the junior secondary level is obvious. (You may notice that the total number adds up to more than 130. This is because some of the curricula span more than one age level.)

fig.1
Distribution of i.s. curricula amongst age levels.



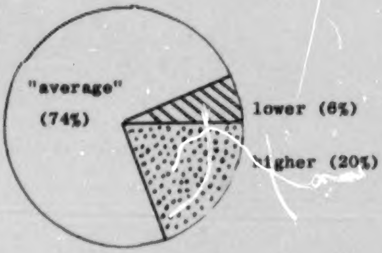
## Ability

Almost all of the courses that we looked at claimed to be designed for all abilities, or for average ability pupils. It is not always clear whether "average" ability refers to the average of the relevant age group in the population, or to the average of those pupils who attend schools. Some of the few projects which have been specifically designed for special ability groups are the LAMP project in the UK, Me and My Environment from BSCS in the United States, and the Physics with Chemistry Project in Israel for lower ability; and Man and the Physical World from Victoria, Australia for higher abilities.

Figure 2 shows the distribution of curricula amongst the three ability groups. Note that all college, and many senior secondary curricula are automatically for higher ability groups since it is only the more able pupils who are still in full time education at that level in many parts of the world. Bearing this in mind, the numbers of courses designed specifically for the brighter child seems rather low. Is this an implication that separate sciences are thought to be more appropriate for them? Or is it that the bright pupils are thought to be able to thrive without any special help?

fig.2

Distribution of i.s. curricula amongst ability levels.



## Country

We have recorded the country of origin of each of the curricula. We doubt if there is any particularly useful way that this information can be grouped, but it may be helpful in interpreting our data to know that something less than one half of the curricula came from the developing countries.

The under-representation of some regions, such as Eastern Europe, should be taken as a reflection of our failure to get information, and not as any indication of curricular inactivity in the area of integrated science.

## Language

This in most cases is the language of the country of origin. Some courses however, especially from the United States, have been translated into many different languages, and in some countries such as Nigeria and India it is necessary to produce curriculum material in a number of different local languages to meet the needs of the population as a whole.

## Origin

This refers to the heredity of the curriculum - whether it was spontaneously generated to meet a local need, or whether it borrowed significantly from other courses. We can place the curricula on a four-point scale of originality:

a. Adapted from elsewhere, with few modifications. LISIP, the Lesotho Integrated Science Innovation Project is an example. This is based closely on the West Indian Integrated Science Innovation Project (WISCIP), the only changes being those necessary to allow for the different flora and fauna.

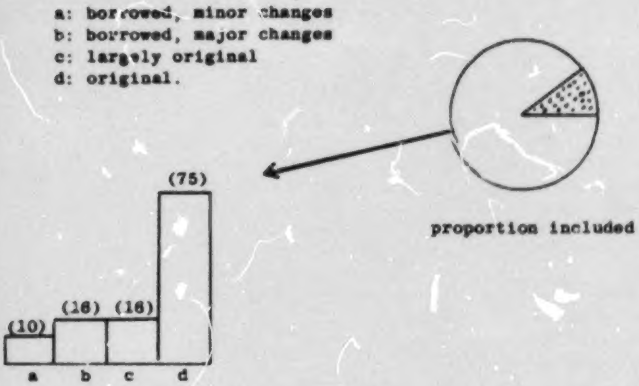
b. Adapted from elsewhere with major changes. SWISP, the Swaziland Integrated Science Project, is in the same family as LISIP and WISCIP but it has undergone a more radical change to allow for differences in local teaching conditions and the needs of local examinations. Other examples of curricula in this category are the Malaysian General Science Project, and Basic Science from Fiji.

c. Mostly Original Material, but with recognised input from other curricula. The Caribbean Integrated Science Curriculum owes something of its structure and philosophy to SCISP, although the material content is quite different. Studies on the Integrated Science Curriculum in Japan is an original curriculum developed to meet local needs, but its initiators studied the successes and failures of other integrated science curricula around the world before starting on their own, and they used some of the ideas that they found suited their situation best.

d. Original. Nothing, of course, is entirely original. Anyone involved in curriculum work must bring to bear their previous experience of science education but if the inclusion of such experience seems general, and does not involve the importation of major structures or sections of other curricula, we have classified the curriculum as "original". Without an intimate knowledge of many families of curricula it is not easy to determine just how original a curriculum is, but examples that we believe owe little to outside influences are Naturwissenschaftlicher Unterricht in der Grundschule from West Germany, and Core Course Integrated Science from Sierra Leone.

Figure 3 shows the distribution of the curricula amongst these four levels of originality. The pie chart shows the proportion of our data bank included in the distribution, since we were unable to classify all of the curricula. The relatively high proportion of courses at level (d) is to some extent a matter of interpretation of our sources. While these sources sometimes provide positive evidence of the ancestry of a curriculum, the absence of such evidence does not mean that the curriculum must be entirely original.

fig.3: Levels of originality of the curricula.



Initiating Authority

The stimulus for curriculum change can originate at a variety of levels within the educational system. We have tried to categorize these levels as follows:

a. School level. One teacher, or a group of teachers in one school, may feel impelled to devise their own integrated science curriculum to meet the particular needs of their pupils and their locality. Their initiative may be encouraged by a flexible examination system, or perhaps by no examination at all. It may also be encouraged by the availability of specialized support such as may be provided by a science centre or from an organization like the Centre for Unified Science Education in the United States. Occasionally such a school based curriculum becomes available to a wider population, and we have identified a few such courses. Two that we might cite are the Correlated Science Program of the P K Yonge School in Florida (which admittedly is a laboratory school), and the Wreake Valley Project in England. The latter originated at the Wreake Valley School but the materials it developed have now been published commercially and are available to others.

b. Middle administrative level. As with the growth of school based projects, recent years have seen a burgeoning of "middle level" initiatives. We think here of initiatives taken by local authorities, by school boards, by teachers' centres, and education research institutes. As examples we could mention the ILEA Eleven to Thirteen Project in London, the projects sponsored by CERD in Lebanon, by ERC in the United States, and by RECSAM in South East Asia.

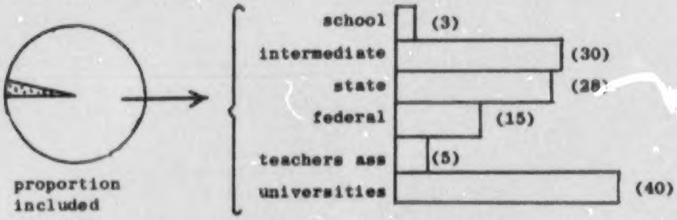
c. National level. National projects are, perhaps, the most familiar. A government department of education may perceive a need in science education, and then organise a curriculum project, sometimes with the help of an aid agency, to meet the need. In some countries we can sub-divide this category into State and Federal level initiatives. Where the distinction is clear, as in countries such as India, Nigeria, and the United States, we have included a Federal category.

d. Teachers' Associations. It is especially appropriate at an ICASE conference to mention the role that associations of science teachers have played in the stimulation of curriculum development. Examples are the Nigerian Integrated Science curriculum from STAN, the Caribbean Integrated Science Curriculum of CROASE, the LAMP project from the UK ASE, and Science - A Process Approach from the AAAS.

e. Universities play a vital role in integrated science curriculum development. They are concerned with tertiary level curricula, but their concern goes much further than this. University science departments may become involved with secondary science curriculum work, and university departments of education take an even more active and direct part in the development of curricula at all levels. Examples of universities' initiatives outside their own course requirements are the MONA junior secondary integrated science curriculum from the University of the West Indies in Jamaica; the Course of Coordinated Science from the University of Palermo in Italy, and the Primary Science Project from Amado Bello University in Northern Nigeria.

Figure 4 shows the breakdown of our curricula into these groups. Classification is often ambiguous since more than one agency may be involved in a curriculum, so these figures can be only approximate.

fig 4: Authorities initiating integrated science curricula.



## Organisation of Course

Integrated curricula claimed to have achieved a blending of subject matter through various approaches: Concept, Topic, Process, Environment, and so on. It is our impression that in every real curriculum these organizing principles are so interwoven with one another that it is impossible to categorize courses usefully under these labels. We can, however, pick out just a few curricula to illustrate the wide variety of integrating factors that are at work.

"Environment" is currently a popular starting point for the integration of the sciences. Topics are studied as the need for them arises from a study of the environment In this paper we have excluded the purely ecological-biological environmental courses, but some integrated science curricula that do depend on the environment for their inspiration are: *The Mauritius Integrated Science Project*, *The Secondary Science Curriculum* being developed at the University of Pavia in Italy, and the *ALECSO Integrated Science* Curriculum.

Other principles, narrower than the environment, have also been used as integrators. The teacher training programme from Kiel, Germany *The Analysis of the Evolution of a Science Concept*, takes the macromolecule as its central concept. Historical approaches to science are the basis of the organization of the SISC curriculum in Japan, and for the *Physical Science for Non Science Majors* program at New York, the solid state forms the integrating theme. One secondary integrated science curriculum originating from Japan, but now in use in other countries, uses the silkworm as the focus of integration.

Finally, it should also be noted that an extra level of organization is provided for some curricula by psychological considerations. For example, Science 5-13 in the UK, MATAL in Israel, and the *Australian Science Education Project* (ASEP) follow a Piagetian line in matching concepts to the developmental level of pupils, while SCISP (Schools Council Integrated Science Project, UK) uses learning hierarchies based on the theories of Gagné.

### Flexibility

How tightly structured is the curriculum? We propose below a four point scale of increasing flexibility. Note that it is not easy to make distinctions between the second and third categories if one relies on the printed material alone. One needs to see the courses in action. Even then, the amount of structure may depend on how the teacher chooses to use the material, rather than on how much the developers intended to build in.

a. *Prescriptive*. The *West Indian Science Curriculum*, and *Naturwissenschaftlicher Unterricht in der Grundschule* are curricula which have very detailed teachers' guides. These are intended to minimise the need for in-service teacher training, and to compensate for rapid teacher turnover.

b. *A series of units with suggested paths*, and possible modifications. Almost any course with a text book must be at least as structured as this. The book itself will be a structuring factor. However, as we noted above, the extent to which this impresses itself upon the teaching depends partly on the nature and confidence of the teacher. We think that the Individualised *Science Instructional System* from Florida falls into this category, and so do the MONA curriculum from the Caribbean, and ALECSO Integrated Science from the Arab League countries.

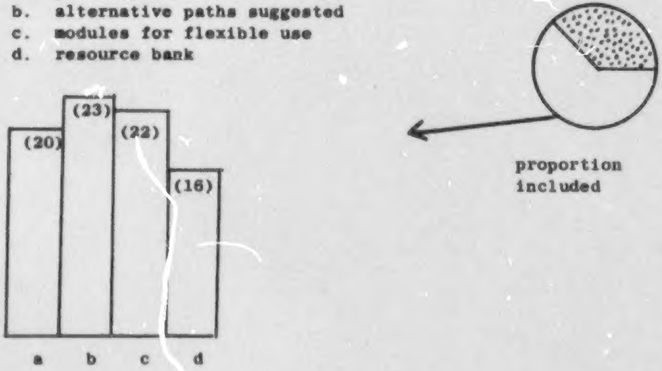
c. *Modules for flexible use by the teacher*. SCISP (UK) is an example of a curriculum that provides "bits" of structured material. These "bits" hold together by themselves, but they may be used in a variety of ways by the teacher to suit his particular needs. Another example is the *Patterns of Enquiry Project* from Ontario, Canada.

d. *A resource bank of ideas* to be picked over and used or left alone as the teacher chooses. An extreme example of this sort of resource bank could not be described as a curriculum, but where there is an integrating theme, or a common thread of philosophy running through all of the ideas, then we have included it in our collection. Primary Science of the Territory, from the Northern Territory of Australia is one example of such a resource bank. Another is SCATE (Student Concerned About Tomorrow's Environment) from Iowa, USA.

Since it was often difficult to ascribe courses to these categories from our sources, the distribution shown in figure 5 is based on just over 60% of the curricula in our data bank. The remainder we were unable to classify.

fig.5: Distribution of curricula amongst levels of flexibility.

a. prescriptive
b. alternative paths suggested
c. modules for flexible use
d. resource bank



## Scope of Integration

We stated above that the idea of scope was introduced by Blum (1973). We have already given an example of a curriculum whose scope is insufficient for it to be included in this review. Of those that are included, we can consider a three point scale:

a. Two science disciplines. Integrated courses may cover only physics and chemistry, or chemistry and biology, or indeed any two of the disciplines commonly taught as separate subjects from the senior secondary level upwards. A common form of two-subject integration is "physical science", but not all physical science courses can be said to be integrated. One that is integrated is Man and his Physical World, developed at the Victoria State Education Department, Australia. Another example is the Course of Coordinated Science: The Structure of Matter from Palermo University.

The BSCS Environmental Module from the Biological Science Curriculum Study Project, USA, may be seen as an example of a biologically based, two-discipline integrated course.

b. Three science disciplines. Into this group fall many of the older integrated science curricula for secondary schools, such as the Scottish Integrated Science Curriculum, and all of the many lower secondary integrated science curricula that have been developed from the same starting point.

c. Two or more sciences plus at least one non-science subject. Integrated courses with a non-science component often reflect a wish to introduce some aspect of social concern. Perhaps the distinction between science and non-science disciplines is not important to the pupils, but it is necessary for curriculum workers and science teachers to be aware when they are straying into territory that may be unfamiliar.

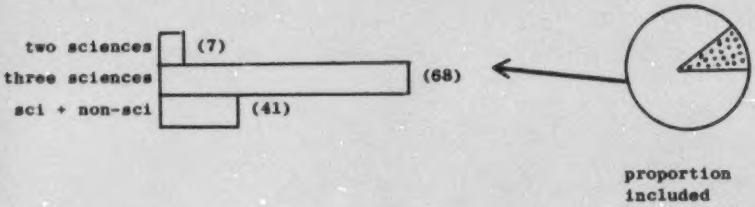
The Schools Council Integrated Science Project in England contains a significant social component, and so do many of the curricula from the United States. USMES (Unified Science and Mathematics for Elementary Schools) is just one example. Environmental Education in the Primary School, from Norway aims to make the pupil aware of Man's social responsibilities, and so may be included in this category also.

We have not included in this category courses which claim social awareness as one of their objectives, but show no sign of it in their printed material.

Other non-science disciplines may also be included with the sciences. One interesting example is in the former Primary Pilot Project from Singapore. In this curriculum, science activities were used essentially as stimuli to the development of language skills, in a country where the formation of bilingualism was once thought to be an aim of primary education.

Figure 5 shows how many of the curricula in our collection fall into each category of scope.

fig. 5: Distribution of curricula amongst levels of scope.



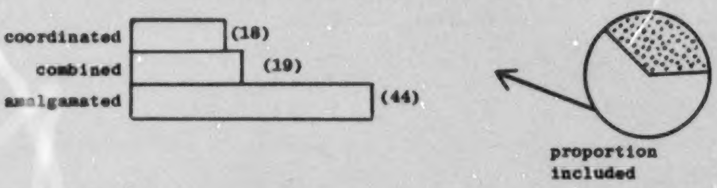
## Intensity of Integration

Blum recognised three levels of intensity of integration of science curricula: coordination, combination, and amalgamation. Briefly, in a coordinated curriculum one is able to distinguish "bits" of chemistry, physics, biology, and so on, but they have been woven together to make a continuous curriculum with a structure of its own. A combined curriculum starts with the ideas of separate sciences, but they are melted together so that the seams between them disappear. An amalgamated curriculum is one that has been developed from the "other end", as it were: ideas which may be associated with separate sciences are called upon as they are needed to cope with problems as they arise from the environment of the learner.

We did not find it easy to ascertain the level of intensity of the curricula represented here, and we had to leave a number as "unknown". We think that the PPS-CN (Projecto de Perfectionamiento en Servicio, Ciencias Naturales) from Chile may be taken as an example of a coordinated curriculum. Basic Science, from Fiji could exemplify a combined curriculum, and the Integrated Science Curriculum of the Tokyo Institute for Education may be taken as one of the many examples of an amalgamated curriculum.

Figure 6 shows how those curricula that we are able to classify are distributed.

fig 6: Distribution of curricula amongst levels of intensity.



Printed material

The most important link between a curriculum project and the teachers who are to implement the curriculum is the printed material produced by the project. The printed matter embodies the curriculum. Almost every curriculum that we have looked at includes an overview of its philosophy and aims, and these are usually worked out in detail in a teachers' guide. Most have laboratory sheets, activity sheets, or some other type of pupils' worksheet, and pupils' books of one sort or another are common also. Tests and other evaluation material are an important part of most projects. Some curricula are heavily dependent on self-instructional materials.

It does not seem practical to try to quantify this data further, but it might be useful to draw a distinction between projects which produce their own material, and those few that are essentially referencing projects. Progress in Learning Science, from the University of Reading in England, is one example of this type of project, which was designed to guide primary school teachers to make the best use of existing curriculum material. Only four or five of our 130 curricula fall into this category.

Audio Visual Material

Slides, filmstrips, tape-slide programmes, and overhead projector transparencies are commonly produced as part of the materials package of integrated science courses. Some courses rely on more sophisticated AV equipment such as videotape. Such courses seem most appropriate where the influence of the course is likely to be wide-ranging - as a teacher training course would be - or in circumstances where there are special communication problems. The New South Wales Junior Science Inservice Project uses a full range of audio-visual equipment in its teacher training programme. In the Lebanon, the Intermediate School Science Project finds slides, tapes, films, filmstrips, and videotape especially useful.

## Laboratory

All of the courses that we looked at demand some practical work, and for the great majority of them this plays a central role in the teaching/learning process. For this reason the demands made on laboratory space and equipment is an important feature of a curriculum. Surprisingly, we found it quite difficult to obtain reliable information on the sort of equipment that was demanded by a course. Initially we had tried to categorize equipment demands as:

a simple: jars and cans and locally available materials;

b basic: microscopes, magnets, wire, basic glassware;

c sophisticated: proprietary kits, meters, energy conversion gear, and so on.

However, it soon became apparent that the concept of sophistication is a relative one. What is basic in one school, or in one country, is sophisticated in another.

The key problem is whether the curriculum demands much more than the school or college is likely to have or can make. If so, does the project include plans for the initial provision, and subsequent maintenance of the equipment? Problems are most likely to arise in countries where science education does not have a high priority in the allocation of the nation's resources, especially where these resources are meagre in any case. The problem is accentuated if the science curriculum has been borrowed from a wealthier country, without due regard to the strain that its equipment demands may throw on a school's economy.

## Implementation

In planning this paper, we had contemplated the possibility of providing some quantitative data about the uptake of curricula. Unfortunately it proved remarkably difficult to determine with any degree of reliability the extent of implementation. In looking through our sources of information we had constantly to remind ourselves that there is no correlation between the number of pupils using a course, and the number of words devoted to that course in the publicity material.

David Lockard has told us that in earlier editions of the Clearinghouse Report he tried asking for the number of pupils following each curriculum reported from the United States. The result was that the sum total of pupils following all courses appeared to be significiantly greater than the whole US school population! There is a natural tendency for all of us who have nurtured a curriculum "baby" to overestimate its impact upon the educational system. Furthermore, as the implementation studies of Nuffield Science in the UK have shown, there are great uncertainties surrounding the meaning of "using" or "following" a course. It can mean just having the course material in the school!

Even if we were able to assess reliably the uptake of courses in schools and colleges, it is not certain that these numbers would be very informative. Some new courses which show great promise may not have completed their pilot stage, and so the number of pupils using them may be low in proportion to their importance. Conversely, where a country has only been offered one curriculum - perhaps through an aid agency - the fact that it is used in every secondary school in the country is not necessarily a measure of its excellence. Judith Reay has pointed out (1977) that the uptake of a curriculum may owe much more to the ready availability of attractive textbooks than to its inherent worth.

In the light of these considerations, we were forced to abandon our attempt to quantify the uptake of integrated science curricula worldwide.

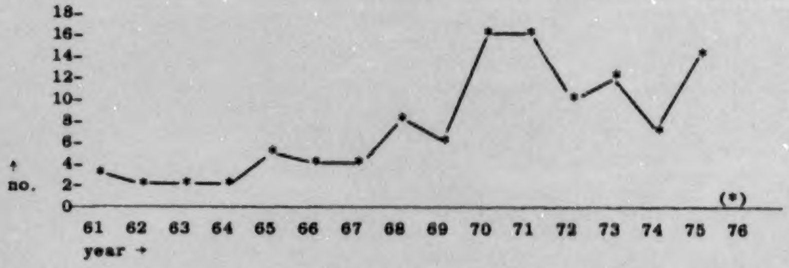
## Trends

One of the major aims of this conference is to identify current trends in integrated science education and it is to this that we now turn our attention. From our survey, one trend is immediately and unequivocally apparent:

### Integrated Science Education is a rapidly-developing and expanding educational field

Ten years ago, at the Varna Conference, there were only 30 - 40 integrated science courses in existence. In our survey we have covered 130, and we believe that many others exist which are not reported in our sources of information. From the dates of inception of each of the curricula in our survey it is possible to plot the number of new curricula starting each year for the 15 years from 1961 to 1976. (The gestation period of curriculum projects is such that few of those conceived during 1976-78 have yet developed to the point of being reported.) This is shown in figure 7.

fig 7: The number of integrated science curricula initiated each year since 1961.



The reasons for the proliferation of integrated science education have been recently well documented by Sally Brown (1977). To summarise briefly there are three major areas of concern which have led to this development, namely: concerns for the nature of science, educational concerns, and social concerns. While historically all of these concerns have, to some extent, appeared contemporaneously, it was concerns with the nature of science and educational concerns that were most prominent when the first integrated science courses appeared. Social concerns came into prominence somewhat later.

A major component of this rapid expansion of integrated science education is a second trend, namely:

## There is a world-wide movement to introduce science into primary school education

An awareness has developed in most countries that science should form part of the education of all citizens, and it has come to be viewed as a basic ingredient in the primary school curriculum. As a first step, many countries have developed science courses which are integrated (or perhaps "undifferentiated" would be a better term) and often of a highly innovative character. Some of these courses are designed for use in primary school curricula which are themselves totally or partially integrated. The majority of these courses have been developed locally in the country or region where they are to be used, although they may owe some of their basic ideas to courses originating in other parts of the world. As pioneer attempts to introduce science at this level, almost all primary science courses are based on direct pupil experience with concrete materials. They tend to emphasize observation, enquiry, the building up of simple science concepts, and an awareness and exploration of the local environment. Such courses imply a major shift in the role of the teacher - from purveyor of information to facilitator of learning experiences. It is this change in role, which may differ from that accepted in the rest of the teacher's work, which poses a major problem in effectively introducing science courses into primary education.

As described in Wynne Harlen's conference paper (1978), attempts are being made through a variety of strategies to initiate primary school teachers (and teachers-in-training) into science teaching effectively. Services are being provided to support the teaching of primary science and to supply resources for it, to diagnose problems and, in general, to enhance the teacher's confidence and motivation. The relatively meagre results which have so far been obtained in many countries with regard to the quality of science teaching at the primary level are leading to a questioning of the strategies that have so far been devised and a quest for ways of introducing science at this level that are more effective.

## There is a rapid and widespread development of integrated science education at the lower secondary level

This trend is closely related to the first two. One of the major areas of concern leading to the development of integrated science courses is educational concern. The Varna conference drew attention to the significance of science education as a component of general education, and the idea of "Education through science" has found widespread acceptance. At the lower secondary level a need has been felt for science courses which are of interest to the pupil and which make a real contribution to his general education. This may well lead to designing courses based on topics and issues closely related to his day-to-day experience. Such topics, by their very nature, often require an integrated or interdisciplinary approach.

The courses designed for this level are still, as at the primary level, based on the extensive use of equipment and concrete materials. Furthermore there is, in many courses, an emphasis on depth in the coverage of a particular topic rather than on the extensive breadth which characterized the older general science course.

At this level the problem of teacher training is less acute than it is at the primary level. However, as indicated at the Maryland conference (1973) much still needs to be done to encourage teachers concerned with this level to teach in an exciting and challenging way so as to interest their pupils in science for the rest of their lives.

### Much greater attention is now being paid to the training and re-training of teachers for integrated science

Reference has already been made to some teacher training efforts in relation to primary and junior secondary school teachers. At the upper secondary level, traditional subject-centredness and the high academic level demanded by some integrated science courses pose special problems for teacher preparation.

The Maryland Conference in 1973 made many suggestions for the development of more effective ways of preparing integrated science teachers. It also identified some of the obstacles to be overcome such as an aversion to integrated science on the part of the teachers. These efforts consist, essentially, of building up teachers' confidence and competence and in promoting a positive attitude to integrated science teaching. The design of pre-service and in-service training courses with appropriate scientific and educational content are contributing to this endeavour. Educational materials, often highly innovative in nature, are also being developed for the training and re-training of teachers.

In many countries, science teachers' associations are actively involved in the design and implementation of integrated science courses. The involvement of the teacher in the curriculum design process is one of the most effective ways in preparing him for its implementation.

### There is a trend towards greater social relevance in integrated science courses

A growing awareness has developed in recent years of the importance to society of the outcome of science education. At the Varna Conference (1968) some reference was made to the social relevance of integrated science education to developing countries, and the issue of social significance of science education was also discussed at the Maryland Conference (1973). Recently, however, much greater emphasis has been placed on the importance of informed public opinion on scientific issues which affect society, and on responsible political leadership in relation to such issues. While concern for relevance is affecting all forms of science teaching - disciplinary as well as integrated - common core integrated science courses have been seen as the most appropriate response to this concern in a number of countries. Such courses emphasise the practical application of science and the role of science and technology in society, typically in relation to the energy crisis and the interdependence of living things.

A socially-related issue which has been well described in John Lewis's trend paper for this conference is that of the swing away from science that is prevalent in many countries. Students tend to view science and technology as responsible for many of the ills of our society but have not found science courses at school or university relevant to the problems that concern them. The development of relevant, interesting, and challenging integrated science courses has been perceived as one way of combatting this trend, and attempts are now being made to design and implement such courses at various levels of the educational system.

## An emphasis is now being placed on environmental issues in integrated science courses

This is one outgrowth of the concern for social relevance. The educational challenges which are posed by science related environmental problems such as pollution, the energy crisis and the rational use of natural resources was reviewed at the recent Intergovernmental Conference on Environmental Education held in Tbilissi, USSR, in 1977. Among the conference recommendations were several concerned with the need to pay greater attention, in school science courses, to environmental issues.

One of the earliest environmentally-oriented courses was the Australian Science Education Project, which has a five point environmental scheme relating to the way in which human beings function - as individuals, as groups, extensions to their perceptions and energies through tools and instruments, in relation to technology and its applications, and in relation to change in themselves and in their environment. At the primary level, the African Primary Science Programme was also environmentally-oriented. Now the trend towards using the environment as an integrating theme has become widespread.

## Integrated science courses in science and technology education are now being developed

A growing awareness has recently developed of the importance of technology education in general education. At the Maryland Conference the distinct but related natures of science and technology were described and the implications of each for the educational process were outlined (Foecke, 1974). Recently a number of courses have been developed in which attempts have been made to combine the methodologies of the scientific approach with those of the technological approach. In such courses children are encouraged to learn skills they need to solve real life problems.

## The scope of integrated science courses is now being extended.

The first integrated science courses covered essentially the basic sciences of physics, chemistry, and biology, and very occasionally elements of earth and space science as well. Recently however elements of other disciplines such as crystallography and marine science have been included in integrated science courses. One aspect of social relevance that has come into prominence recently is that of health and nutrition. These are areas that require not only intellectual understanding on the part of the student, but also a personal conviction of the value of certain health and nutritional practices. As stated in Isias Raw's conference paper (1978) "there is no topic that is more real, relevant, and personal than the student's own health and nutrition....An integration of science with health and nutrition education, which includes an objective presentation of the rationale for health and nutrition recommendations will have a much greater chance of success in being accepted by students." At the International Conference of Nutrition Education held in 1977 such an approach was strongly endorsed. As yet only a few courses of this type have been produced, but some modular units are being developed.

## Attempts are being made to inter-relate integrated science courses with other curriculum areas

Reference has already been made to the concern with education through science, which has been one of the major motivating influences in the integrated science education movement. In seeking to develop scientific attitudes and skills it has become apparent that other curriculum areas, especially mathematics and language, have an important role to play. At the primary level some projects, such as the Yoruba project in Nigeria, attempt to integrate science, mathematics, and language.

At the secondary level, greater attention is also being given to the relationship between mathematics and science. A recent UNESCO - supported project is focussed on cooperation between science teachers and mathematics teachers. The Continuing Mathematics Project in the UK is one example of an attempt to design modular units related to particular topics in the school science curriculum.

## Much more attention is being given to evaluation in science education

At the Maryland Conference in 1973, evaluation of integrated science education was identified as an area where little information was available and which required urgent attention. Since then, a number of activities have taken place at international, regional, and national levels to promote evaluation of integrated science curricula, and to assist those involved in such attempts. A meeting organized by ICASE, with UNESCO support, in 1975 attempted to review current knowledge and practice in the field and to exemplify it through a series of case studies. The proceedings of the meeting were published by UNESCO as New Trends in Integrated Science Teaching Volume IV (1977). Following a number of national attempts in African countries to evaluate integrated science curricula, a meeting was held in the Seychelles in February 1978, at which such attempts in eight African countries were reviewed. Comparable evaluation efforts are being made in other parts of the world.

## In the design of integrated science courses, the results of educational studies and research are being applied

If curriculum development is to be effective, pupils must be provided with learning experiences that are appropriate to their level of mental development, and intellectual demands must match pupils' abilities. In recent years attention has been drawn to the study of childrens' thinking in science. Much of this study has been focussed on the development of logical thought by children, based on a Piagetian model of cognitive development. Other researches are also being conducted in relation to the learning of specific science concepts, and also in relation to children's cultural backgrounds and belief patterns.

Attempts are now being made to apply the results of such studies to the design of integrated science courses. These attempts include the holding of workshops and seminars for research workers, curriculum designers, and practising science teachers, and the inclusion of studies of children's learning in teacher training programmes. The results of studies on spatial abilities of children and on language development are also being applied to the design of integrated science courses.

## REFERENCES

BROWN, Sally. *A Review of the Meanings of, and Arguments for, Integrated Science*. Studies in Science Education, IV, 1977

BLUM, Abraham. in New Trends in Integrated Science Teaching Vol II, 19pp

FOECKE, H A. in New Trends in Integrated Science Teaching Vol III, 1974, pp 1-7

HARLEN, Wynne. *Strategies for the implementation of integrated science education at the primary level*. Conference paper, Nijmegen, 1978

LEWIS, John. *Science in Society*. Trend paper, Nijmegen, 1978

RAW, Isias. *Developments in integrated science education in relation to Nutrition and Health Education*. Trend paper, Nijmegen, 1978

REAY, Judith. *Summative Evaluation of Caribbean Integrated Science Projects*, in New Trends Volume IV, 1977

Maryland: Conference on the Education of Teachers for Integrated Science, 1973. Reported in New Trends Vol III.

Varna: Congress on the integration of science teaching. Bulgaria, September 1968.

## 2.3 The Case for Teaching Science as a Unity

Dr V Showalter, Center for Unified Science Education, USA

It is an honour and a privilege to have the opportunity to present to you "The case for Teaching Science as a Unity" The title carries the implication that some adversary will follow my talk with "The Case *Against* Teaching Science as a Unity". If that were so I would be most fortunaqe because you, the jurors, are undoubtedly biased in favour of the affirmative or you would not be attending this conference.

However, I suspect that the real jurors are those colleagues at home who resist teaching science as a unity - at least for the present. My talk then will focus on the arguments that support the unity of science as a basis for teaching science and, hopefully, will provide each of you with some "Ammunition" to be used *with* conservative colleagues. I do not like to think of using this kind of ammunition *against* colleagues who think science should be taught as separate and discrete disciplines because I am reasonably sure that their primary concerns *are* for students for whom they really want the best education possible. I have never met a science teacher who did not desire, deep in his or her heart, to do what is best for students. I *have* met a few who act as though they are more interested in reciting the well worn catechism of their own specialty regardless or in spite of student needs to the contrary.

I am not suggesting that we science teachers abandon our personal science interests. I *am* suggesting that these interests should not interfere with students achieving a broad and useful background in science that will be meaningful to all and a springboard to careers in science for a few.

From the foregoing, it should be apparent that I want to argue for teaching science as a unity to all young people involved in that level of education which is pre-specialization. This level of education is sometimes referred to as general or liberal education. It may extend only to age eleven in developing countries or it may extend to age eighteen or twenty in developed countries. National economic needs of course take precedence in determining how much general education can be afforded for all persons. Worldwide trends though are toward extending this period of general education both before the individual becomes committed to a job or career and, also, after he or she becomes employed.

And so, the case for teaching science as a unity is based mainly on the premise that it be done as an integral part of a general education programme for whatever age group one specifies.

This does not deny the responsibility of a general education programme to motivate a critical proportion of younger students to eventually specialize in some specific science or science related field. As will be seen later, there is empirical evidence that teaching science as a unity does in fact fulfil this responsibility.

It seems to me then that, within the contexts just described, the case for teaching science as a unity is based on three types of arguments: philosophical, psychological, and pragmatic. I propose now to discuss each of these in turn.

But first, I must acknowledge the fact that I am charged with being an advocate of teaching science as a unity. This is not a difficult charge to accept since that is what I believe is best for the education of all people. Nevertheless there are opposing arguments that can be offered and I may mention a few of these as I proceed.

After all, controversy is the life blood of science. Without controversy, progress does not occur. And so, in thinking about science, we will do well to do it scientifically and not try to avoid controversy.

Also - there is another scientific reason for admitting opposing views to our discussion. That reason is based on results of a study which showed that if you want to convince someone of something he or she is most susceptible to an 85-15 proportion of positive or negative arguments. That means that a set of 100% positive arguments is less convincing than a set which contains 15% negative arguments.

When we first consider the business of teaching science we must be clear on what we mean by "teaching" and "science". By "teaching" we mean that something happens by design which results in some person or persons learning - developing knowledge that is intellectual or cognitive, or developing attitudes or feelings, or acquiring some manipulative skill. Benjamin Bloom labelled these domains of learning, "cognitive, affective, and psychomotor".

Teaching may or may not involve a live person who has the role of teacher but it always involves a live learner. And the learner is somehow different after the teaching with respect to Bloom's "domains".

Teaching also implies that there is some specific subject matter abstracted from previous human experience that will serve as the arena in which the various domains of learning can and will occur. In our present concern, that subject matter is science.

Many philosophers have attempted to define science. I rather like Philip Phenix' view that science is one of several distinctly different "realms of meaning", or ways of knowing. As such, the knowledge that we associate with "science" has a set of properties that distinguish it from knowledge associated with other ways of knowing.

Science as a way of knowing also includes a set of unique procedures or processes which are regarded as "standard" or acceptable in generating new knowledge. Thus, science is characterized by and differentiated from other ways of knowing by the nature of its knowledge and the procedures by which new knowledge is generated.

Some of the distinguishing characteristics of science knowledge are:

1 - It is based on public evidence as contrasted to personal evidence which cannot be shared or replicated by others.

2 - It is tentative and will change in the foreseeable future.

3 - It leads to probabilistic predictions as contrasted to absolute predictions.

These are in contrast to other ways of knowing in which knowledge may be based on personal evidence and is absolute in that it will not change and certain aspects cannot be questioned.

It should be obvious that these characteristics of science knowledge hold for knowledge in all the sciences. Science knowledge that applies to plants and to rocks may, on the surface, seem to be as different as are the plants and rocks but on close examination the nature of this knowledge is the same - the separate sciences of botany and petrology are integral parts of the larger science. Their differences can be thought of as differences of degree rather than of kind.

As a way of emphasizing this last point let us contrast mechanics and sociology in terms of the ways new knowledge is and has been generated in these areas. Scientists in both areas often take great pains to obtain quantitative data in order to accept or reject a given hypothesis. Ordinarily there is an effort made in this process to control all variables except the one that is suspected of being a causative agent in the situation investigated. By giving the suspected variable a variety of values, it is possible to observe the effects on the system being studied and to attribute these effects to the variable being manipulated. A critical problem in this approach is to successfully control all of the variables. It is in the degree of success in controlling variables that mechanics and sociology differ. When we deal with inanimate physical objects, we feel we are quite capable of limiting external forces and conditions. However, in dealing with living individuals we are not so successful since they cannot be closed off from the rest of the world. Thus the sociologist is forced to make calculated corrections that will counteract whatever variables changed that he or she wished could have been held constant.

Again note that the difference here between sociology and mechanics is one of degree rather than kind. In mechanics experiments it is relatively easy to control variables while in sociology it is very difficult to do.

In speaking about controlling variables, we have entered the process dimension of science which involves the generation of new knowledge. Taken as a set the processes of science distinguish science from other ways of knowing. Some of those processes in addition to controlling variables are: inferring, observing, questioning, measuring, hypothesising, interpreting data, etc.

These processes are common to all science and thus form one argument for the unity of science. Taken individually there is probably no one of these processes that by itself is unique to science but taken as a group they are.

The centrality of the processes to the overall endeavour of science becomes apparent only when one considers that the processes essentially do not change in time. The processes used by Galileo are the same used by this year's Nobel Prize winner in physics. Unlike the knowledge of science, the processes are permanent. This does not mean that humans have not developed the processes to greater levels of complexity and power because they have. Interpreting data today can be accomplished by using many sophisticated techniques that simply were not available in Galileo's time. Yet even today, young children interpret data in relatively simple ways that undoubtedly are the same as was done 300 years ago.

The universality of the processes of science is further emphasised when we realise that any one of the processes can be "done" by any person at his or her own level of sophistication. Thus, anyone can generate new knowledge for himself in science and it seems logical for people to be educated to use these processes on an everyday basis.

Let us now consider a third argument for the unity of science. Just as a common set of processes are used to generate or build scientific knowledge, so there seem to be a common set of concepts which serve as the bricks from which this knowledge is built.

The term concept has been used in several different ways. Here we use the term concept as learning psychologists do. Thus, a concept is an idea that is usually expressed by a single word. It must be mentioned that in some literature, a concept is taken to mean a statement such as "the sun is the source of all the earth's energy". It is too bad this practice has become as widespread as it has because what then shall we call energy, equilibrium, entropy, etc...? The statement is better labelled a principle. Some concepts are generalizations from real world experience. Examples of these are: chair, red, dog, and dissolve. These have been abstracted from our personal experience with a number of real things or events. Each of us has differing levels of richness for our concepts depending on the extent of our experience. One of the joys of getting older is that our concepts get richer providing we are continuing learners and attuned to our environment.

But the kind of concept we are speaking of as forming a unifying bond in science is a slightly different type. These "other" concepts are abstract ideas or mental inventions. Margenau has called them constructs and they are powerful intellectual entities which enable statements of scientific principle or law to be more general than if we were limited to concepts derived from the "real" world.

Energy, equilibrium, system, population, and force are examples of key concepts or constructs that seem to permeate all science. The concept of equilibrium is used in such traditionally diverse sciences as chemistry, physiology, geology, and psychology, etc. In some cases the actual word used may be different such as homeostasis and isostasy. Chemists may argue that there is a difference between equilibrium in its strict sense and the idea of steady state. Nevertheless, the basic idea expressed in all of these is the same.

Gerald Holton of Harvard has traced the historic recurrence of several of these basic concepts, which he calls "themes" in his book Thematic Origins of Scientific Thought. Holton's thesis is that certain themes or concepts seem to be so ingrained in science that they form the very fabric of science. Scientific progress then amounts to developing these concepts to ever more complex levels.

It is obvious that not all concepts in science are equally useful throughout all the separate sciences. There are special concepts that seem to be unique to certain sciences but if they are really powerful inventions, they have a way of being adapted by other sciences very quickly.

As an example consider the concept, "System", which was invented in 1938 by Bertallanfy, a biologist. The concept was quickly appropriated by scientists in other fields and today is used in all sciences. As an example, one of the better recent American textbooks of introductory geology is titled "The Earth's Dynamic Systems". In the preface to this book, the author emphasizes that the system concept has a powerful organising function in bringing together or uniting a large number of previously separate aspects of geology. Thus, the earth's tectonic system, hydrologic system, atmospheric system, etc can be discussed in the common conceptual framework of "system" and students can see the underlying unity of what otherwise seems to be many unrelated phenomena.

Once the pervasiveness of these crucial concepts and the effects they have in unifying science are acknowledged, we, as science teachers usually start to wonder how many of these concepts there might be and which ones might be appropriate for teaching in our particular school situation. We at the Center for Unified Science Education have identified a list of about thirty. Needless to say this list is rather arbitrary and many heated discussions have been provoked when someone suggests adding or deleting a particular concept.

A fourth line of reasoning that gives additional substance to the idea of the unity of science is the common value base that underlies all science. Scientists of 50 or more years ago were in general agreement that their efforts were totally objective and, therefore, value free. We now realise that this "objectivity" is really the product of a set of seven values.

In fact, the prestigious Educational Policies Commission of the American National Education Association has gone on record as recommending that an understanding and appreciation of these values should be the principal product of school education in science and that learning about these values should take priority over any and all of the traditional science content.

Whether or not we want to agree with such a radical position is not the point here. What we do need to realise is that these values do underlie all science and as a set are unique to science. That is they contribute strongly to the unity of science.

The specific values identified by the Educational Policies Commission are:

1. Longing to know and understand.
   A conviction that knowledge is desirable and that inquiry directed toward its generation is a worthy investment of time and other resources.

2. Questioning of all things.
   A belief that all things including authoritarian statements and "self-evident" truths are open to question. All questions are prized although some are of greater value than others because they lead to further understanding through scientific inquiry.

3. Search for data and their meaning.
   Prizing of the acquisition and ordering of data because they are the basis for theories which, in turn, are worthwhile because they can be used to explain many things and events. In some cases these data have immediate practical applications of value to mankind as in cases in which data enables one to assess accurately the severity of a problem in society and/or the effects of policies directed to improve such situations.

4. Demand for verification.
   A high regard for requests that supporting data be made public and that new empirical tests be invented and/or conducted to assess the validity or accuracy of a finding or assertion.

5. Respect for logic.
   An esteem for those chains of inference that lead from raw data to conclusion according to some logical scheme and an insistence that conclusions or actions not based on such chains be subject to doubt.

6. Consideration of premises.
   A prizing of frequent review of the basic external and internal assumptions from which a line of inquiry has arisen, especially when they are used as a basis for determining further action.

7. Consideration of Consequence.
   A belief that frequent and thoughtful review of both the direct and indirect effects resulting from pursuing a given line of inquiry or action is worthwhile and that a decision to continue or abort the inquiry or action will be made in terms of the consequences.

A fifth philosophical argument for the unity of science is expressed very nicely in the words of the great American naturalist John Muir who said:

> "When you reach out into the world and grab hold of something, you find that it is hitched to everything else."

This is a rather nice way of saying that we live in one world and that things and events in it are manifestations of the same natural order and system. The historic allocations of natural phenomena to particular science disciplines are conveniences and very arbitrary. The idea that all trees belong to the province of Botany may be useful to botanists - at least initially. But there comes a time when botanists exhaust their traditional lines of research and vitalization of inquiry can come only from other disciplines. The result is a blurring of disciplinary lines in spite of the continuance of college departments, professional journals, annual conventions, and the other trappings of the traditional discipline.

Although it seems inevitable that professional scientists must specialise in something, one wonders whether the traditional specialities are really functional. These are the same specialties that serve as the basis for our textbooks and course outlines in school science.

Margenau commented on the apparent obsolescence of traditional science disciplines by saying: "Today the lines are no longer so closely drawn, so that almost all the traditional disciplines, even astronomy, can be regarded as departments - or more loosely, as aspects of what might be called the scientific mode of knowing."

But what of the trees we mentioned? How are we to understand them? How are we to fit them into our own personal cognitive network? A single discipline does not help much. A mix of a few disciplines would be better. Using all science without regard to particular disciplines would be best. Because each discipline today has something to a common understanding of trees. Botany, chemistry, plant physiology, geology, meteorology, climatology, ecology, and very likely economics are needed to help us understand trees in anything like their entirety. This summation is a holistic kind of knowing and besides being personally fulfilling is somewhat of a guarantee against our acquiring an incorrect or distorted understanding of trees.

Many of you have undoubtedly heard the story about the several blindmen who touched various parts of an elephant and then told what the animal was like. Each reported something quite different. The one who touched a leg said the animal was like a tree. The one who touched the trunk said it was a snake. The one who touched an ear said it was like a palm leaf - and so on.

Each blind man was correct - so far as he went. But each was also quite wrong in terms of the whole thing. An accurate holistic view could only be approached by pooling all the specialised observations and even then some features would be missing.

A holistic understanding has more than improved accuracy to recommend it. A holistic understanding is also more satisfying to the individual than is understanding which is obviously fragmented and incomplete.

I will illustrate this point with a story that may at first seem to be non-scientific although I would argue that it is a matter of perceptual psychology.

During the previous International Conference on Integrated Science Education held at the University of Maryland in 1973, several of the participants expressed an interest in observing some American go-go dancers. Although that is not my main field of specialisation, I agreed to sacrifice some time one evening to lead a "field trip" to enable these interests to be met.

The first place we visited was Archbold's in downtown Washington. I had been there once or twice before and hoped we could get seats close enough to the stage so we could see the performers reasonably well. The hostess led our intrepid group closer and closer to the stage and finally seated us at the very edge of the stage itself. We could not have been any closer.

But within a very few minutes we all realised that we were too close. One could watch this part or that part at any one time but never the whole dancer. At any moment each of us was as restricted in the extent of our observations as were the blindmen and even though we could change the focal point of our observations from moment to moment the overall effect was not satisfying - in fact it was not even interesting. In addition we were so close that the ultraviolet light used on the stage caused our eyes to fluoresce and even our limited specialised views were blurred.

By analogy then, it can be argued that a unified view of natural phenomena is inhibited by getting too close or too specialised. That personal satisfaction requires getting back far enough to have a feeling that the whole is being perceived. That science should be taught as a unity.

The persistent problems of society of many situations parallel to that of "Trees" and other natural phenomena are leading to a unity of science. These persistent problems are those at the interface of science-technology-and the rest of society which are being given high priority by all nations. Among these problems are energy supply, food supply, water pollution, population control, and many others that seem as if they will be with us forever but which social forces demand we address.

Ritterbush in his contribution to a recent conference convened by the American Science Policy Foundation with the Commission of the European Communities suggests that the basis for seeking science understanding may be better founded in a concern for action, that is in working toward solution of problems, rather than in pure curiosity as has been characterised by the separate specialised sciences. After all, research today requires huge amounts of money and amounts of this magnitude are only available from national governments and large corporations both of which require some "payoff" in the relatively immediate future. The appropriate payoff is in terms of at least partial solutions to a particular persistent problem.

This insistence on tangible results is made even more pointed by efforts such as the United States Senator Proxmire who makes weekly reports on "esoteric, non-practical research" projects that have been funded by some branch of the federal government. Public resentment against some of these projects is so high that continued support has been threatened even though many of the projects are "basic" in the view of traditional disciplinarians. The only research that seems to acquire public support is that which is "mission oriented" or directed toward understanding and/or treatment of one of the socially significant problems in some way or another.

The problems like trees require input from a variety of the traditional sciences. Actually, the demands of these problems are such that new specialties are being formed which combine relevant aspects of many older specialties. Thus a water pollution control expert specialises in science knowledge and processes that were previously separated as parts of physical chemistry, organic chemistry, parasitology, virology, mechanics, etc.

Unification of the sciences is occurring, in part, in many of these new specialties. At least the spirit of integration is being developed by necessity and an added measure of legitimacy is given to such efforts.

These steps toward unification of the sciences are sometimes protested by spokesmen of the traditional separate sciences. Often the protesters are from one of the biological sciences and most often the protest is based on a fear of reductionism. They say, in effect, that life cannot be reduced to physics. But this is an appeal that argues from an oversimplified premise. After all one of the characteristics of science knowledge is that knowledge in any branch of science must be consistent with, or at least not contradicted by, knowledge in other branches of science.

And so, let me now summarise the components I have cited as philosophical arguments for teaching science as a unity. They are:

1 - the nature of scientific knowledge

2 - the processes of generating new scientific knowledge

3 - concepts used in expressing scientific knowledge

4 - values that underlie the scientific enterprise

5 - satisfactions implicit in holistic explanations and perceptions of natural phenomena

6 - forces tending to dissolve the boundaries among traditional sciences in mission oriented research.

All in all, it appears that in science itself there is a principle of complementarity operating in that both analytic and synthetic thought are required for viability. It further seems that we are nearing the end of an era in which analytic thought has dominated and we are entering an era of new emphasis on synthetic thought which may well establish new frameworks for analytic emphasis in the next era which will commence exactly x years from now.

Let me now turn to the second principal line of reasoning that supports the Case for Teaching Science as a Unity - that of the Psychological.

It is difficult to draw a clear line separating the philosophical and the psychological but here we will assert that the philosophical arguments relate to science itself and the psychological arguments relate to the human processes of learning science.

The first psychological argument for teaching science as a unity involves the selection of educational objectives for science teaching. Undoubtedly, the selection of objectives will be and should be influenced by our philosophy of science. In fact, to be intellectually honest, the objectives we choose should be entirely consistent with our philosophy.

Our educational objectives in science should also be consistent with our understanding of how people learn science.

One of the great arguments for teaching science as a unity is that both of these logical principles can be followed.

A group of us at the Center for Unified Science Education has researched the literature related to what many thoughtful people from a variety of background have recommended as important outcomes of science education for all. Not surprisingly perhaps, it turns out that a distillation of these recommendations relate very closely to a philosophy which views science as a unity.

We have come to speak of these general objectives as eight dimensions of scientific literacy because they represent eight directions along which every person should make a satisfactory degree of progress in order to be generally educated in science.

Each of the eight dimensions of scientific literacy that I will describe briefly here has also been explicated by a set of performance factors which can be used at the actual classroom instructional level. Time precludes an in-depth discussion of these factors here although a poster session later in the conference will be dedicated to the topic.

It should be emphasized that these eight dimensions are presented to you for your consideration and not with any sense of absolutism. In other words, these dimensions are not "carved in stone" although many people dedicated to teaching science as a unity have found them to be very useful.

The scientifically literate person:

1 - Understands the nature of scientific knowledge

2 - Understands and accurately applies appropriate science concepts in interacting with his or her universe

3 - Uses processes of science appropriately in solving problems, making decisions, and furthering his or her own understanding of the universe

4 - Understands the values that underlie science and consciously choose to apply them or not in interacting with his or her universe

5 - Understands and appreciates the joint enterprise of science and technology and the interaction of these with each other and with other aspects of society

6 - Has developed a richer, more satisfying, and more stimulating view of the universe as a result of his or her education in science and seeks to extend this education throughout his life

7 - Has developed numerous manipulative skills associated with science and technology

8 - Has developed an ability to think on the formal operations level as described by Piaget and others.

It will be noted that the first five of these dimensions are derived directly from the arguments supporting a holistic or unified philosophy of science.

Dimension 6 says in effect that the individual has found science to be personally relevant, rewarding, and worthwhile. Obviously this too relates to science as a unified whole and not just to one of its specialized branches although an enduring interest in one of these branches is not precluded. It refers to a generally favourable predisposition toward science and admits a wide range of levels including career dedication to some aspect of science.

Dimension 7 involves the development of a general comfortability with the hardware of science. It is difficult to describe the variety of these manipulative skills except in terms of specific types of instruments and equipment. As with the other dimensions, this one can be thought of as a continuum ranging from the relatively simple to the very sophisticated. Thus the manipulative skills range from the ability to use meter sticks and equal arm balances through microscopes and sphygmomanometers to pH meters and recording spectrophotometers.

Dimension 8 acknowledges that understanding science on a mature level requires that the individual be able to think on an abstract level. As most of you know, Piaget and others have operationally defined a transistion from "concrete operational thought" to "formal operational thought" that can and may happen in humans as early as the age of twelve. However, it appears that for as many as 60% of eighteen year olds, the transition has not occurred. Facilitating this psychological transition is largely the responsibility of science education since it is known that certain types of science learning activities, do, in fact, catalyze the transition. It seems to matter not which of the special sciences is used to develop the transition and in fact may be enhanced by a mix of activities from a mix of the special sciences.

It will be noted that the eight dimensions of scientific literacy offer a relatively simplified framework for science education objectives that has several psychological values

1 - Emphasis on a relatively small number of concepts each of which is very powerful thus enabling learners to discern the important from the trivial. These concepts provide powerful advance organisers that are applicable to a large number of subsidiary ideas and will in all likelihood be useful to the learner throughout life.

2 - Emphasis on active doing rather than completely passive receiving especially in dimensions of skills and processes.

3 - Emphasis on social relevance as in the dimensions dealing with science, society, technology and personal interest in science.

4 - Emphasis on the affective or attitudinal domain as in the values dimension.

5 - Emphasis on cognitive development level so as to remove the most formidable barrier to further mature understanding of science.

As a group, the dimensions of scientific literacy not only reflect a unified science philosophy and a holistic psychology but also unite these two important determiners of how and what science shall be taught.

Thus far I have tried to build a case for teaching science as a unity without saying anything about how it might be done. I am certain that there are many possible ways in which science can be taught as a unity.

Depending on how the teaching is done there are several additional psychological arguments to support the teaching of science as a unity.

One of these is that when something is taught in multiple contexts the probability is enhanced that the learner will be able to transfer what is learned to a new situation. This means that if a fifteen year old were to learn something about the concept of equilibrium by way of examples from physiology, chemistry, ecology, physics, geology, and psychology, he or she would be psychologically better prepared to use the concept in a real life situation than if the concept had been learned in just one context such as chemistry.

The same argument that learning in multiple contexts facilitates transfer is equally valid for learning related to any one of the dimensions of scientific literacy. Thus, the process of interpreting data will be more transferable if the data comes from a variety of special scientific areas and manipulating electronic apparatus will be a much more generalizable skill if it is practised with a pH meter, a spectrometer, and a pulse meter than if experience is limited to one of these.

Another psychological argument for teaching science as a unity can be found in the fact that doing so is a departure from tradition. Therefore, teachers using the approach are not so bound to using the teaching/learning methods that have become "standard" in the conventional sciences.

Although there is nothing to prevent teachers of traditional science subjects from incorporating a variety of learning modes, tradition dictates that certain modes are more acceptable than others.

For instance, among most chemistry teachers, there is a belief that reading, lecture, and laboratory modes of learning must be used but that using gaming as a mode of learning is not quite respectable in spite of educational research that shows gaming to be a powerful mode especially among students with little "normal" motivation.

The importance of using a variety of learning modes in teaching science, or any school subject, probably cannot be overemphasised from a psychological point of view. One of the principal causes of students losing interest in science is the teacher's use of one mode to the exclusion of all others. Even laboratory when it is used as the sole mode of learning becomes tiresome after a while. The occurrence of the monomethodology syndrome is unfortunate when one considers that there are at least 20 modes of learning and more may be provided by new technology in the future.

A somewhat similar psychological argument can be made in relationship to the structure or format of learning materials or units. Since teaching science as a unity is non-traditional, there are fewer forces tending to impose traditional formats. In teaching science as a unity, it is quite easy to prepare units of study in which not all learners are required to do exactly the same things. In such units, there may be choices for learners so that individual differences in ability, learning style, cognitive level, and previous experience can be accommodated.

From a psychological point of view, it is very desirable to individualize learning, and teaching science as a unity removes some of the traditional barriers to doing so.

In summary, the psychological arguments to support the case for teaching science as a unity have been:

1 - Learning objectives for teaching science as a unity can be easily and directly derived from a philosophy which views science as a unity.

2 - The number of major learning objectives can be kept relatively small and limited to truly important aspects of science.

3 - Learning in multiple contexts, which typifies most approaches to teaching science as a unity, facilitates learner transfer of what has been learned.

4 - The number and kind of learning modes used is expanded.

5 - The format or structure of learning units is opened to variation which can accommodate individual differences and extend interest.

Having now considered philosophical and psychological arguments, to support the teaching of science as a unity, let us now turn to the third and final category - that of pragmatic or practical arguments.

Probably the one most obvious and consistent effect of teaching science as a unity in the United States has been the dramatic increase of elective enrolment in science at the high school level. As many of you know, only one year of science is required in most American high schools (ages 15-18). The usual trend in recent years has been that fewer and fewer students elect more than the required minimum except where science is taught as a unity and in these places the trend is reversed.

If we can assume that elective enrolment in science is a fair indicator of student interest in science, then teaching science as a unity does increase student interest which is a necessary condition for extending people's education in science.

Other studies have shown that college students who have studied science as a unity in high school obtain as good or better grades in first year college science courses than do their peers who have studied science as separate subjects.

Another finding has shown that a greater proportion of students going on to college from high school programmes in which science was taught as a unity tend to major in science. This should give some assurance to those who worry that teaching science as a unity will have adverse effects in terms of numbers of future scientists.

Yet another finding shows that students who study science as a unity score higher on tests of scientific literacy than do their peers who have studied science in conventional ways. This argument is somewhat restricted however because there is still a lack of test instruments that are applicable to all the dimensions of scientific literacy.

One of the weaknesses of the effects I have been reporting is that the studies on which my statements are based are essentially limited to the United States. It seems that most studies of the practical effects of teaching science as a unity in other countries has been limited to primary and junior secondary levels. I believe that the upper secondary and even tertiary levels must be studied and positive results obtained before teaching science as a unity will achieve the status of complete acceptability in the science community.

In general, the studies done at primary and junior secondary levels around the world show that the objectives of the programme are indeed achieved. Along with these findings, there have been some unanticipated associated gains. A notable gain of this sort has been an increase in measured reading ability that has accompanied many efforts at teaching science as a unity even though such progress is not specified in the objectives.

It is possible of course that many of these gains have been induced as part of a Hawthorn Effect. That is, both students and teachers may perform at higher than usual levels when they know they are part of a special or unique group. In most cases when science is taught as a unity, both teachers and students realise that they are doing something difference and the Hawthorne Effect is possible. Nevertheless, based on what little evidence is available, the gains I have reported seem to be persisting and thus cannot be wholly attributable to the Hawthorne Effect.

Whenever one discusses the practicality of teaching science as a unity, especially at the high school level, the question of who will do the teaching inevitably arises. One of the arguments against teaching science as a unity, is that many teachers for one reason or another say that they would rather not - that they are comfortable in teaching science as separate subjects. Some feel that their background is unsuited to teaching science as a unity. It is difficult to discern the exact cause for not wanting to change.

Consider the results of a follow-up study we did of teachers who had attended an intensive three day workshop in teaching science as a unity. As most of you are aware, each local school district in the United States has almost complete autonomy in determining the local science curriculum. Therefore, our follow-up study asked if teachers had decided to teach science as a unity or to continue with traditional science courses. Further, the study sought reasons for the decision. Practically all of those teachers who said they were not making a change said the decision was based on the fact that they enjoyed what they were doing. On the other hand, those who said that they had decided to teach science as a unity invariably replied that their reasons had something to do with potential student benefits. This is an interesting contrast especially when one considers the purpose of having schools in the first place.

Now, I do not mean to imply that teachers' feelings are unimportant because they are. In fact some of the most universal practical effects of teaching science as a unity involves the teachers themselves. One of these is that teachers report a renewed personal interest in and enthusiasm for teaching science and for learning more science themselves. Secondly, teachers report new feeling of partnership with their fellow science teachers. They seem to develop a heightened sense of working cooperatively toward common goals of science education and this seems to benefit students as well as teachers.

Those involved in teaching science as a unity sometimes experience considerable stress in deciding to give up some of the traditional content of science. They are very desirous of adding some of the new content derived from viewing science as a unity but it sometimes takes a while to realize that tradeoffs must be made. All of life seems to involve tradeoffs and nothing is gained except at the expense of something else.

The emerging role of the science teacher as an interpreter of all aspects of science requires that he or she has the professional competence and courage to make these tradeoff decisions cooperatively with their colleagues.

In summary, I have considered three groups of arguments to support the case for teaching science as a unity: Philosophical, Psychological, and Pragmatic.

The philosophical arguments revolved around the central idea that science is a single unique human endeavour. That science is one of several ways of knowing and that the separate sciences differ only in degree not in kind.

The psychological arguments centered on the importance of the human learning process as a rational codeterminer of science curriculum.

The pragmatic arguments focused on the empirical confirmation of desirable outcomes of school science as they are associated with teaching science as a unity.

In conclusion, it should be obvious that the idea of teaching science as a unity is still developing - that those who choose to become involved are not alone but that there is still much to do - and to travel hopefully is better than to arrive.

## 2.4 Reflections on the Implementation of Integrated Science Teaching

Dr F James Rutherford, National Science Foundation, USA

### Introduction

About a decade ago many of us were in Varna, Bulgaria, enjoying the Red Sea, plum brandy and gypsy dancers, and - in response to the nudgings of our professional consciences - sometimes attending the working sessions of the first international congress on integrated science teaching. Half a decade ago, some of us attended a second such conference held at the University of Maryland, where, as I understand it, session attendance was much higher. Not myself having been there, I can only take such a result to constitute a strongly negative commentary on the hedonistic attractions of College Park, Maryland.

My reference to the ancestoral predecessors of this present conference, while offered in jest, is not without purpose. The substarce of my reflections on the implementation of integrated science teaching will make sense, if at all, only in the perspective of the Varna and Maryland conferences. The three UNESCO volumes, New trends in integrated science teaching /1,2,3/, contain all of the essential ideas of these conferences, and so I have taken them collectively to represent the substance and spirit of the conferences themselves. Moreover, those three documents collectively stand, in my judgment, as the most thoughtful and complete statement on integrated science teaching as it is conceptualized and practised at all educational levels in many parts of the world.

What I propose to do in this paper is to review the Varna and Maryland conferences briefly in the context of implementation. I will argue that the strong underlying premise of both meetings was that integrated science teaching is vastly superior to traditional discipline-oriented science teaching, and that, consequently, it is important that such instruction become the standard science offering in the general education curriculum of our schools and colleges. I will then contend - as ironic as it may seem at first - that this enthusiasm for integrated science may very well have led us to the adoption of an implementation model that is very unlikely to lead to the desired end result. The implementation model implicit in both of the former conferences will then be contrasted to an alternative model - one which can perhaps best be thought of as a non-implementation implementation model. I will close with a reference to an actual project that is using this alternative model.

## Varna: Why teach integrated science?

Appropiately enough, the Varna Conference dealt primarily with two questions. In one way or another, nearly every paper or report addressed itself to the question, why teach integrated science? While most participants and authors were already firmly convinced that science teaching ought to be integrated in content and style, the opportunity was taken by most contributors to defend that belief. The other question receiving major attention at Varna was: what is integrated science teaching? Some speakers addressed that question directly, others implicitly by presenting examples, but no one ignored it.

Let me try to summarize the main reasons given for why we should teach integrated science. My intention is not to affirm or deny them, but explore them for the implementation questions they raise. I will return to them later to cast some doubt on their certainty. The case for inegrated science teaching is predicated on assumptions about the natural world, science, students and societal needs. In telegraphic brevity these are:

- The natural world is a unifield whole. Our present lack of knowledge may prohibit us from perceiving that unity in all its complexities, but to the extent possible science should try to illuminate the whole rather than the mere fragment that each separate discipline concerns itself with. Questions: How can a teacher ever get to know enough about the astronomical, atmospheric, ocean, earth, biological and physical sciences - not to mention mathematics and the behavioural and social sciences - to be able to teach unified content? Unless teachers will agree to substantially broaden their knowledge of science by studying sciences outside of their own field, is there any way they can become prepared to teach an integrated view of the world (or any part of it)?

- Science itself, as distinct from nature, is moving toward integration in content and method. More and more separate conglomerates of knowledge are being assembled into a conceptually unified structure, just as techniques are shared across disciplines. The rapid development of molecular biology provides a dramatic but not atypical example of what happens when different sciences join hands. Questions: Can a teacher trained in substance, techniques and style of one science learn those things about one or more other science domains without extensive retraining? Can a teacher learn "integrated science" de novo? Will he even try if it takes him into areas of science about which he has no personal interest?

- Technical and career education aside, students are rarely interested in the kinds of questions that relate to the theoretical structure of a given scientific discipline. Instead they wonder about the real world of their everyday lives. Such matters willy-nilly cut across discipline boundaries, and therefore so should science teaching if it wants to capitalize on natural student interest. Question: Since different students have different science-related interests, how can any one integrated science course deal with them any better than a discipline-structured one?

The major societal issues of our times - disease, overpopulation, resource depletion, environmental degradation, and the like - are linked to science and technology. If citizens of the world are to deal effectively with such issues, then surely they need to understand science broadly and in the context of those problems rather than narrowly in the context of compartmentalized disciplines. Questions: How can teachers develop the vast knowledge it would take to deal with so many problems scientifically? How would they keep up to date in several sciences simultaneously? Can they learn to deal with science-related social issues in a non-biased way?

## Varna: What is integrated science?

I will return to the rationale for teaching integrated science later, but let me now turn to the other concern of the Varna Congress, namely to the question, just what is integrated science teaching? It was agreed that two conditions had to be met. One had to do with content, the other with format. As the Varna Congress report put it, integrated science teaching requires "...joining several subjects into a single course in which the concepts of science are presented through a unified approach." The examples given to illustrate this in both Volumes I and II differ enormously from each other in scope and conception. In terms of content, examples include:

- Courses that merely blend material from different sub-divisions of a single major discipline.

- Those that select material from two or more separate sciences.

- Some that join one or more of the natural sciences with mathematics or with material from the social sciences, arts or humanities.

- And those that put material from one or more sciences together with applied science and technology.

As for format, the diversity presented is even greater. As Marjorie Gardner and I suggested in a paper in Volume I of New trends in integrated science teaching /4/, most of the courses that claim to be "integrated" can usually be placed in one or more of the following categories:

- The conceptual scheme approach in which the over-arching ideas of science (conservation of energy, evolution, ecological balance, atomicity, plate techtonics, etc) provide the unifying thread.

- The inquiry approach in which solving problems and answering interesting questions about the natural world takes precedence over particular content.

- The relevance approach in which the content is organised around questions of the social utility and impact of science and technology.

- The process approach in which engaging students in doing science, any science, is considered to be more important than student mastery of a prescribed body of scientific knowledge.

As this suggests, the Varna meeting demonstrated that a vast array of interesting kinds of integrated science courses are possible, but also that no concensus formed, then or later, as to which were best. From the implementation viewpoint this raises many difficult questions. For example: In a given situation, who selects from among the array? If, on the other hand, no single choice is made and many different integrated courses find their way into the schools, can pre-service programmes be designed to produce sufficiently versatile teachers? How will textbook publishers cope?

## Maryland: Preparing teachers for integrated science

The Maryland Conference took the next logical step by beginning to address the implementation issue. It asked: how can we get teachers to teach integrated science? Some of the answers were complex in that they called for the involvement of many different institutions (universities, schools, professional associations) and categories of people (teachers, supervisors, parents, students, evaluators, scientists, educational scholars). But however simple or complex the plan, the focal point of concern was the science teacher. Whether concerned with pre-service or in-science preparation, or both, the various groups concluded that preparing teachers to teach integrated science, meant outfitting them with a proper array of knowledge, skills and attitudes. One group, for instance, listed ten goals of teacher education for secondary school teachers of integrated science, almost none of which are currently goals of traditional teacher education. The conclusion that emerges from Maryland is that the successful implementation of integrated science courses must wait on a complete reorganisation of the teacher education system.

## Integrated science teaching as a goal

I have tried to present the thrust of the Varna and Maryland Congresses fairly but from a special perspective, namely that of implementation. The analysis has led to some doubt, on my part at least, about the soundness of the classical implementation process as applied to integrated science teaching. The logic we have tacitly used seems straightforward and sensible, on the face of it once the initial premise has been accepted. Briefly put, the argument is: integrated science is better for students than discipline-oriented science (premise); we know how to design integrated science courses (fact); therefore we ought to replace traditional science with integrated science (major conclusion); and in order to do so we must see to it that our science teachers are suitably prepared (contingent conclusion). Clearly the operating assumption from which the rest follows is that achieving integrated science instruction ought to be the main purpose of modern science education.

But should it? I would like to suggest that the answer is no. No, because the basic rationale on which the assumption is based is not irrefutable. No, because the goal of general education in science is better expressed in terms of the quality and richness of the school science learning experience than in terms of the introduction of any particular kind of science curriculum, integrated or otherwise. No, because the acceptance of integrated science as a goal seems to lead to an implementation process that is inappropriate and ineffective.

As to the rationale for integrated science teaching based on claims that the universe is a unified whole and that science is becoming unified, let me repeat comments made by Rutherford and Gardner /5/:

> Grand philosophical notions about the "ultimate" nature of the universe are speculative at best, and certainly views counter to

the "unity" one expressed above, are held by some philosophers. The modern trend, perhaps, is neither to affirm nor to deny the oneness of the universe, but rather to say that such speculation may be interesting but not terribly useful. Many scientists would claim that what they are really doing is trying to solve limited problems that happen to interest them, whether or not the solutions of these problems contribute to the construction of any unified view of the universe.

Similarly, it is the position of many contemporary philosophers and historians of science, not to mention scientists themselves, that conceptually and methodologically, science is not and cannot become totally unified. There are those who do not believe that eventually all of the natural phenomena of the world (whether chemical biological, astronomical, geological, physiological, psychological, or whatever) can be organised and explained completely using physical laws. Those who take such a view can point out that even within the house of physics itself, unity is illusory, as evidenced, for example, by the need to rely upon such concepts as wave-particle duality and by the falure to develop a unified field theory.

As far as the practice of science is concerned, it is no longer widely believed that there is such a thing as the scientific method. Instead, there seems to be a variety of methods used by different scientists in different fields at different times. The biologist ordinarily cannot simply switch into chemistry, say, and be a productive researcher. It is not only that he may not be up to date in his understanding of chemistry, but also that he will be lacking in the investigatory skills appropriate to the state of the art in that field.

The facets of the rationale that justify integrated science teaching in terms of student preferences and societal needs, can be countered by presuppositions such as:

- So-called real-life objects or events cannot be explained "holistically" but only by bringing to bear knowledge from the individual sciences or subsciences.

- There is no agreement in sight on what particular knowledge is needed by scientifically literate citizens, on how sophisticated the knowledge needs to be, or on how intimately the knowledge needs to be connected with a particular societal concern.

- Certain kinds of integrated science issues do not address societal issues or student preferences any more than strictly disciplinary ones, and, conversely, certain discipline-oriented courses are able to deal effectively with both societal concerns and student interest.

Thus I submit that if our aim is to replace all disipline-oriented science for the general student with integrated science, our case is moot at best. But even if the rationale were unassailable, such a goal is misplaced because it results in putting a particular kind of teaching approach too far up the ladder of educational values. The quality of the learning experience in school is of far more consequence in science or any other field, than the content dealt with or its organisation. Unless integrated science can be shown to be the only way to achieve an intellectually and emotionally rewarding school science experience, then it should be viewed as an important but not singular curricular alternative.

## The goal-related model for implementing integrated science

If integrated science teaching is set as a goal, then it follows that integrated science courses and materials must be introduced into the schools and teachers must use them, that is, the goal logically implies the need for implementation. A review of the papers associated with the two previous conferences reveals, I believe, acceptance of a classical implementation model. This model can be characterised as (1) having a curricular orientation, (2) being serially ordered, (3) seeking radical change, and (4) favouring external validation. Let me discuss each of these attributes in turn.

First of all, most efforts in the name of "Integrated Science" have had a strong curriculum focus. As you go through New Trends in Integrated Science Teaching, for example, you find that the overwhelming number of articles have to do with the design of one or another kind of integrated science course, with issues of subject matter selection and content organisation predominating. Although some contributors presented their ideas in the context of particular regions or countries, or of age or developmental levels, the emphasis is rather more on the curriculum than on the context.

While most of the integrated science literature has emphasised the curricular aspects this is not to say that the role of science teachers has been ignored. Typically, teachers get into the act at two points in the process. It is now rather widespread practice for curriculum development groups to test their materials as they are produced by having a few carefully selected teachers try them out in their classrooms. On the basis of feedback obtained from such teachers the experimental curriculum is modified and retested, and this process is continued until the developers are satisfied or the money runs out. After the course and course materials are felt to be ready, and they become available, the effort is begun to persuade large numbers of teachers to adopt the new curriculum and to teach them to use it. In other words, most teachers come into the picture primarily as the proximate target of implementation activities.

Secondly, I note that in the traditional model, the various components generally occur pretty much in a linear or serial order: Curriculum development; followed by dissemination (to persuade education officials and science teachers that they should agree to the adoption of the particular integrated science course being offered); followed by teacher preparation; followed in some instances by continuous supervision and evaluation.

Notice that in a serially ordered implementation model the action flows pretty much in one direction only. Each prior step has to be successfully completed before the next step can get fully under way. As a result, the only teachers able to influence directly the content and structure of a new integrated curriculum or participate in the development of the materials are those very few teachers who work with the curriculum developers.

The integrated-science-as-a-goal implementation model is radical in the sense that it seeks to bring about a rapid and large scale curricular discontinuity, namely to quickly replace one kind of content and instruction with another kind. Radical change may seem attractive, but rhetoric aside, schools show little enthusiasm for it, and when confronted with such a possibility they show truly impressive powers of resistance.

Finally, this implementation model calls for external validation. That is, teachers in a given school district or locality must generally accept or reject a proferred new integrated science course pretty much as it is because they lack the authority and expertise of those outside experts who designed it. Tinkering or minor adaptation may be possible in a region in order to have a curriculum accommodate local preferences, but little more is possible as long as local or internal validation is not built into the process of curriculum change.

## A non-implementation model for implementing integrated science

If not, then, to "implement" their curricula, what other ways are there to utilize the enormously creative work of those who are committed to integrated science teaching? As a first step in beginning to frame an answer let me suggest that we need not accept the goal as stated. We can, after all, think of many ways in which to improve science instruction that do not involve the introduction of integrated science teaching. We also know that to inject integrated science curricula into the schools is not by itself sufficient in order to bring about the quality of science instruction that most of us feel is necessary. By changing our perspective so that integrated science teaching does not become an isolated goal in and of itself, we are free to explore how best to use the concepts and techniques of integrated science teaching in order to enrich and energize the whole science learning ambience in our schools. By coming to think of integrated science as instrumental to a higher goal rather than as constituting an end, new implementation vistas are opened to us.

This change in perspective leads, I believe, to a different implementation model. By contrast with the model described above, we can think of an implementation plan that is (1) teacher oriented, (2) non-serial, (3) progressive and (4) locally validated. Such a model is, by its nature, more complex and less direct than the one commonly used, but I believe that it is more likely to achieve enduring results. Let me explore this model with you.

All of the research and experiential knowledge we have about the effectiveness of science teaching tells us that the teacher and not the curriculum is central. Research has not always been successful in identifying exactly those professional and personal teacher characteristics that differentiate the outstanding teacher from the good teacher from the poor one; however, it has been well established that in order to teach any subject well a teacher needs to believe in it and in his ability to teach it. The scientific disciplines are established, have a history, are represented by generations of textbooks that change only incrementally, are connected to the scientific community through existing societies (scientific and teaching) and journals, are built into the school and college organizational structure, and, all in all, seem comfortably familiar to most science teachers. Confidence and conviction are the natural outcome of this, and abstract philosophical arguments we may use to defend integrated science teaching are unlikely to prevail. The fact that there is little unanimity on what constitutes the best approach to integrated science teaching only makes it harder to persuade teachers that they should give up discipline-oriented teaching.

Some strategy, therefore, other than confronting the teacher, each teacher, with a new curriculum to be learned, introduced and taught is essential. The teacher who is to use a new curriculum needs to be in on the process in a way that is more than symbolic. If teachers come to want to teach integrated science - exclusively or non-exclusively - then is the time to work with them to achieve this.

On the other hand, teachers themselves are usually not able themselves to develop new curricula, especially such dramatic departures as integrated science. In fact, they probably have no way to even become interested in it unless and until they can see actual examples in print and in action.

Fortunately there is a way out of this chicken-and-egg dilemma. Enough good integrated science materials are around, and enough avenues exist, such as pre-service and in-service programmes, to make it possible to develop teacher awareness of the many possibilities that integrated science teaching offers for enriching the context of science teaching. As this awareness grows, so may demand, and so may the willingness of the teachers to work with outside specialists in developing at least some integrated science activities of their own. In other words, curriculum development and implementation, including everything that needs to be accomplished to improve science teaching in a particular place, should all be happening at the same time.

This is messy, not at all orderly, and yet provides the basis for a gradual but steady improvement of science instruction; and is very likely to include, as teacher understanding develops, the establishment of integrated science teaching on a scale and in a context suitable for the teacher and his students. Teacher orientation rather than a curriculum orientation is compatible with such a non-linear, non-ordered approach to the improvement of science education. It presupposes that everything improves more or less simultaneously, even if not smoothly or rapidly.

And slow it probably will be. This implementation model can be seen to be incremental. Rather than calling for radical change that tries to achieve a discontinuity, this one settles for steady, progressive change. Most educational revolutions fail since systems reject radical change; perhaps an evolutionary process will achieve more in the long run.

This model, being evolutionary, possesses no beginning and is never completed. It asks us to undertake a continuous, neverending effort to upgrade science teaching in a given locality and in the process to involve the cooperative efforts of teachers, school administrators, curriculum analysts, scientists, university specialists and others. Internal demand rather than official decree should be the driving force behind the gradual development of integrated science teaching.

This raises the question of validation. Should a new curriculum be sent in from the outside already fully designed and tested by experts, perhaps to be modified to fit local conditions and desires? Or should the local setting be the point of origin of the demand for an improved science curriculum and the site of some of the developmental work? This model opts for the latter.

Many curriculum projects have been criticised because they seem to work well while they were in the experimental mode but less well or with less acceptance when an attempt was made to implement them widely. The positive results obtained while the projects were on their experimental phase were often attributed to the notorious Hawthorne Effect, and thereby discounted. But the power of the Hawthorne Effect in educational experiments probably has to do precisely with the development of commitment and understanding on the part of the very persons who can finally make a new approach work or fail. The developers of new courses, integrated or disintegrated, are generally not pleased to have years of work "tampered with" locally; nevertheless, the solution offered here is to have local influences (via teachers, administrators, students, parents) being exerted from the outset. The validation of instruction should be determined by local, ie internal, results, not by external authority.

This is not to say that the model presupposes the ability of individual school districts or regions to develop a new curriculum on their own. Indeed it is clear that a forward looking curriculum, say in integrated science, can only be built by persons having a deep grasp of the scientific subject matter, a familiarity with the social problems on which science and technology bear and special creative skills. Instead the claim is made that, if invited, persons having such knowledge and skill can work with local authorities in developing integrated curriculum for that location, and do so even while certain other activities associated with the improvement of science teaching in that locality are also taking place. The outside specialists serve the inside authorities, not the reverse.

### A current example

The description of the non-implementation implementation model outlined above, leaves out many details, of course. Dozens of questions remain, such as just what is "local" in this context, how is leadership provided in such an amorphous cooperative enterprise, and how can useful goals be defined? Rather than dealing here with such details, perhaps it would be better to conclude by describing one project in the United States that is currently using a model somewhat like the one above.

Project City Science, funded by the National Science Foundation, does not bill itself as a "curriculum development project" but rather as a "cooperative systems approach to the improvement of middle school science teaching in New York City." By middle school in this instance is meant roughly those grades which serve youngsters ages 11 through 14. In fact the project works with only two of New York City's 32 school districts, each of which has a character of its own and about six middle schools. These districts and New York University, which jointly originated the project, have committed themselves to work together for at least the next decade on this effort.

There are many aspects to this project, but let me mention here only those that have some direct bearing on the eventual use of integrated science teaching in these districts. The following activities are occurring simultaneously:

- In each participating school there is an on-going team made up of faculty and students from the university, school administrators and science supervisors, and all of the school science teachers who are anxious to work steadily on the improvement of their teaching. The teams have gradually grown to include most teachers. Collectively the team-members decide what to work on and how to proceed.

- Each team has agreed to conduct on-going needs assessments, calling in whatever outside help is necessary in order to learn how themselves to analyze their curriculum and methods. As part of this - but only part, since science curriculum is not the only focus of concern - the science curriculum at each grade is studied in relation to science in the other grades, to other subjects, to the nature of the students in that school, and to the broader needs of society. In every case, as it happens, there has come from this study a gradual understanding that teaching the individual science disciplines in isolation is not satisfactory, and a growing conviction that something can and ought to be done about it.

- The university-based members of the team, composed of science and science education faculty members and doctoral students who are being especially trained to be clinical professors, spend up to three days a week in the schools working on the solution of problems as defined by the teachers and administrators. They quickly established their credibility as helpful solvers of problems rather than as academics trying to impose curriculum reform on the schools. We find, therefore, that the ideas, materials, plans, etc, that the university members of the school team bring in begin to be paid attention to after an initial exploratory period. This applies to ideas about and examples of integrated science teaching.

- Most practising middle school science teachers readily admit that they lack the breadth of scientific knowledge suitable for the actual teaching situation in which they find themselves. Their formal training has usually been in one science, say biology, but they find themselves teaching content from the physical and earth sciences as well. To deal with this situation the university team makes available in-service courses especially designed to fill each teacher's lacunae. Also, an integrated science capstone course is offered to those teachers who wish a novel review of up to date science without having to repeat old courses or submit to ones that are too advanced for them. For this they receive credit from the university with the cost being borne by the school district. But note that while this allows the teachers to experience integrated science learning, the course is not billed as preparation for integrated science teaching. Rather it is offered as a service to teachers to help them teach better what they already teach. That it may also open their eyes to a new way to teach science is a bonus.

- For a year the pre-service teachers in the programme are required to spend three to four days per week in these same participating schools. There they are required to test out a variety of strategies and methods including - but not exclusively - integrated science materials put together by themselves. This gives them experience in teaching such units and at the same time presents the "master teacher" an opportunity that is nonthreatening to observe such instruction. As part of their academic pre-service training these students are also required to take a year long course in integrated science after they have had sufficient preparation in the physical, biological and earth sciences and one or more courses that relate science, technology and society. Thus they have an opportunity themselves to experience such instruction. The integrated science course is taught as a straight science credit course, and each quarter of the course is designed on a different unifying principle.

- After a year of cooperative work with the teachers and administrators in the actual situation, and after interest had developed, the university group started preparing some initial integrated science materials. These serve as raw materials for a variety of activities and as the beginning of serious curriculum development in the participating schools. Thus all of the teachers who might eventually use such materials are involved in their deveopment, in one way or another, even if, in some instances, it is no more than helping to make a selection from among various approaches or materials. Activities and unit materials developed or suggested by inventive teachers are seriously tested.

- In discussing curriculum alternatives, integrated science is used as a focus precisely because it raises fundamental questions about the nature of the universe, of science knowledge, of scientific methodology, of students, of the science-society interaction, and, of course, of teaching methods. As an instrument for the improvement of science instruction, integrated science teaching seems to have more impact than it does as a singular goal.

It is too early to know whether this experiment will work or not, but at least two things seem to have been demonstrated. ONe is that cooperative university-school teams can be put together, learn to work together, and stay together. Secondly, the process can lead to a concensus on what is needed to improve science instruction that includes a readiness to move towards integrated science teaching. Progress is slow, but it is there and seems firm. If it ends up taking ten years to bring about, among other improvements, at least some integrated science instruction that is understood, supported, and properly employed by the teachers, then that may be more than sufficient to justify the use of such a complex implementation model. If the quality of the science teaching improves even though integrated science does not find its place, well that is all to the good also.

The Project City Science experiment may or may not prove to be effective, and the implementation model upon which it is based may turn out to lack power. In any event, I think it is now time for us to become more inventive in coping with the implementation problem if we are ever to make real headway.

## REFERENCES

1. New trends in integrated science teaching, Vol I. Prepared by P E Richmond. (Paris: Unesco, 1971). This volume includes papers selected to describe and illustrate the principles expressed at the Varna (Bulgaria) Congress on the Integration of Science Teaching in 1968. This congress was organized by the Inter-Union Commission on Science Teaching (ICSU).

2. New trends in integrated science teaching, Vol II. Edited by P E Richmond. (Paris: Unesco, 1973). Commissioned papers and literature review that collectively present an analysis with examples of trends in integrated science teaching.

3. New trends in integrated science teaching, Vol III: Education of teachers. Edited by P E Richmond. (Paris: Unesco, 1974). Based on the proceedings of the ICSU Conference, "The Education of Teachers for Integrated Science - Teaching Science for Today's Society", held at the University of Maryland, USA, April 1973.

4. Rutherford, F James and Marjorie Gardner, "Integrated Science Teaching", New trends in integrated science teaching, Vol I, 1968, 51-53.

5. Ibid, 49.

## 2.5 Environment as an Integrating Factor in Science Education

Dr Rais Ahmed, Vice-Chancellor, University of Kashmir, India

Education is a basic human need - both for the development of the individual and the advancement of society.

Unfortunately the role of education in providing knowledge, skills and attitudes to the individual has been traditionally overemphasised, or sometimes the needs of the individual are supposed to be in conflict with those of the society. I am afraid at least the developing countries cannot afford to endorse this concept. The common people of our countries live under conditions of great material deprivation with shortages of food, drinking water, medical help, shelter, clothing; - of practically everything that makes even animal-like existence possible. It is impossible under these conditions to speak of the growth of the individual - meaning thereby the growth of the finer human qualities - without in the same breath speaking about socio-economic development of the society we live in. Indeed, the two are linked because in the absence of development, only a few individuals can manage to uplift their soul, while in the absence of education and enlightenment of the population at large economic development would have to be ordered from above, either with foreign assistance or through a benevolent dictator or perhaps both.

There is no alternative before a democratic society other than to consider education a basic human need, in fact an instrument for the satisfaction of other basic needs, an instrument of socio-economic development. A society which is compelled by historic circumstance to adopt a dynamic system of ideas and programme must of necessity make inputs in education as a part and parcel of the inputs in agriculture, health, industry, social services, and community development - such a society must also demand that the inner structure, content and methodology of education should conform to the concept of simultaneity and synonimity of individual and social development.

Even a cursory study of the conditions and processes of education would reveal that if the essence of the relationship between education and development is not grasped, education will remain the preserve of the affluent and a means of their pre-eminence in any country, all the fine words about democracy, or socialism notwithstanding.

I would like to cite the interesting example of India in this connection. Soon after independence when our Constitution was framed, universal compulsory primary education was entered as one of the directive principles of the Constitution, to be achieved within a period of ten years. The founders of the Republic gave universal elementary education a priority over, for example, the provision of clean drinking water in the villages! Nevertheless, since educational plans were not integrated with plans of other sectors of socio-economic activity and since neither course structures nor curricula nor even school management were geared to socio-economic development, today 26 years after the adoption of the Constitution, 60% of children initially enrolled drop out of school before completing five years of education; and today we have more illiterates in the country than we did when the Constitution came into force. Our excellent universities, technical institutes, and research laboratories notwithstanding; our considerable achievement in scientific and technical self-reliance notwithstanding, our common people, particularly the majority of our population in the rural areas have neither benefitted from the prestigious yet peripheral development nor have they contributed in fair measure to general advancement of our society.

I am sure the same is true in many other countries. With the best of avowed intentions, education has remained the preserve of the economically privileged, just as the other fruits of development have gone to this section of society. As a whole, want and misery have remained widespread and often threaten to destroy the very fabric of a democratic society. Side by side, as a part of the democratic process, the politician who goes begging for the common man's vote is confronted with the facts of the common man's existence and is obliged to see the link between education and social welfare and social justice; he is forced to admit that injustice is inherent in the very nature of present day education. It is thus that he is made at least to voice, enlightened policies.

It is gratifying to note that the experience with the struggle for development has convinced a number of countries and a large number of educationists that a fundamental change in our approach to education is necessary, and that education has to become a vehicle of cultural, social and economic transformation in our countries. If its concern is merely the individual without an equal concern for the actual circumstances in which the individual functions - namely the social and economic conditions, then such an education will assume a bookish and pseudo-scholastic character and it will be pursued by only those who can afford to give up, in favour of studies, all activities designed to earn a living; it will in the long run either create alienation between the educated and the masses, or perhaps breed dissatisfaction with the society without creating the will and ability to change it.

As far as internal design of education is concerned, the three key words representing the new outlook seem to be relevance, action and cooperation.

Relevance refers primarly to the curriculum. Traditional courses particularly at the school level seem to have been designed, by and large, with a consideration of what one has to learn at college, or perhaps, from the point of view of building up systematic knowledge of the various disciplines. This helps bring about almost a world-wide similarity in these courses, but at the same time it has contributed greatly to the high drop-out rate. Not only may this curriculum be criticised from the points of view of structure of disciplines and the cognitive development of children, but also because it provides non-functional knowledge to the vast majority of children who terminate their studies before reaching the college level. Children in the rural areas particularly find the content of the course to have no bearing on the kind of lives they live, the experiences they come across and the problems which the communities face. Since in the first place they are brought to the school through a measure of persuasion, they are ready to drop out when the school programmes prove of no interest to them.

We are therefore obliged to think in terms of recasting the curricula, making them relevant to the learner and his society, and making the knowledge and competencies involved to be functional. This is not only a pointer but a clear indication that the curricula must be environment based and adopt an integrated approach. We are interested in bringing about some learning regarding the occurrences, phenomena, problems, situations and other entities, which the child comes across, and we want him to acquire the skills and attitudes necessary to meet the challenges of those situations. We are not interested in laying the groundwork for physics, chemistry or biology as such but, for example, in creating a competence to eradicate malnutrition and disease. The elements of this competence are likely to spread beyond the three disciplines mentioned - to biochemistry, health science, sociology and creation of an anti-obscurantist scientific attitude. The primary concern is to enable the learner to become a more rational and autonomous person, a more useful citizen even if he spends only a few years in formal education.

If relevance refers to learning in the context of the total environment - in keeping with the life, needs and aspirations of the people, the concept of "action" refers to intervention in the situations, or rectification of the problems under study. This is again a radical departure from the traditional concept of schooling or education where passivity, acceptance of life as it is, and dispassionate aloofness are implicit in the process. It is common experience that learning which is confined to the books soon degenerates into information gathering and memorziation - and in the semi-feudal societies of most of the developing countries leads to a false glorification of the abstract, the theoretical and the "purely" mental. Children even from the peasantry and the working class strive to imbibe the white-collar attitudes and culture, alienating themselves from the life of their families and people. This, in so small measure, has contributed to skepticism towards education in the families of the first generation learners and amongst the illiterate people.

On the other hand there is a great deal of evidence to show that working with ones own hands; trying to do a thing oneself, and being actively involved in a process or a problem leads to much better motivation and learning. When questions arise from practice or from ones own experience, answers are sought with an earnestness which would be rare in the case of hypothetical questions and answers. The answers are also subject to the test and scrutiny of practice thereby avoiding uncritical acceptance of what is handed down by the teacher. No further elaboration of this point will be undertaken here because there is ample literature on this, and in particular the great Indian patriot and educationist, Gandhi, had founded his concept of basic education through similar premises. A number of countries have in fact been implementing these educational ideas for the last few decades. Education partly undertaken through production in the schools and community service by the students has been experimented with, and with a good measure of success.

The point here is that environmental education through an integrated (science) approach should be combined with action programmes to modify the reality, to change the "environment" in which the community lives, to contribute to local development. In our countries where the illiterate are also cultured, rural life has a vitality of its own. The myth and the superstition combines with fatalism born of centuries of feudal and caste domination, and all this becomes an impediment to every kind of desirable change. If education is visualized purely as a mental exercise it will not alter life even a little and it will be considered both harmless and fruitless; a luxury which poor countries cannot afford. But on the other hand if a study of actual problems becomes the source of learning; and if by concrete action based on the study, the problems seem to be eroded to some extent, there will be great attraction for such education. Education in this case will attract funding and will in fact generate resources of its own.

Of course action or work orientation of education is adopted with due consideration of the age group of students involved - from handling simple tools and materials to play with, or to make playthings and decorative articles at the earlier age, to fabrication of useful and saleable articles and participation in the gathering of relevant information (through observation, surveys and field trips) planning and designing and implementing developmental projects (such as improvements in the disposal of waste, or eradication of malaria) and services on a local level, at the secondary education stage. Care has to be taken that these activities do not become merely mechanical and repetitive and that learning of an appropriately wide scope, including the learning of techniques and skills are always aimed at, resulting in giving a creative bent to the endeavour.

Educational programmes which would consciously encourage learning based on a vast variety of locally and personally relevant work and experiences will not produce an attitude of disdain and contempt for work, and will lay the foundation of skills and knowledge which would prepare the learner for a possible vocation at the end of schooling. This also has the potential of the school acting as an intermediary for technology transfer, since intelligent performance of work could lead to improvement of processes and products with the application of modern knowledge - the sources of which could be made accessible to the teachers through external measures.

Obviously, not only is there tremendous scope here for environment based integrated science education, but also it is the only form of education in which action orientation could possibly be given at school. Separate disciplines would leave our vast areas of useful knowledge, and their corresponding "practicals" or "laboratory" could not possibly deal with the study and solution of live problems, since most processes and products span over a number of traditional subject areas. Again, environment based integrated education could be adapted with positive results in non-formal situations. We may remind ourselves that many developing countries have come to realise that the formalism of the school is itself an impediment to the spread of education amongst the most deprived sections of our population and that non-formal strategies are obligatory. To be effective in such population groups, educational experiences have to be even more intensely relevant and contributory to family and community resources and welfare than is the case with the formal school system.

The third feature of the new educational approach is that developmental needs, including the needs of creating new social attitudes and awareness, can provide a set of action points around which learning may proceed, but the participants in action and in teaching-learning are both the school as well as the community. A programme of education generally "beneficial" to the community can not, even in principle, be imposed on any community - and the community will own it only if it is a partner in evolving and implementing the programme. This is a concept on which much has been written in recent years, and which is being put into practice in several countries. It would suffice at this stage to say that total environment-based and action oriented education can only be implemented when the human and material resources of the community concerned can be tapped - in teaching, during field studies and while undertaking concommitant action - conversely the school acts as the catalyst for engaging the students and the rest of community in providing concrete benefits to the concerned people.

Obviously this interaction is out of question with fragmented disciplinewise teaching - the community would not be interested in physics or chemistry - but in problems of food, health, shelter, social services, psychological adjustment and culture. It is perhaps due to this consciousness of the role and purpose of education that in a very large number of developing countries "integrated science" has been accepted in principle and introduced at the elementary education level - ie up to about 14 years of age. However due to a variety of factors integration is not real or proper, the environmental and action bases are partially or totally missing, while community involvement is in an experimental stage. There are numerous problems in bringing about such a change in education, not the least of them being lack of social and political commitment, and the inertia of the old system to which no alternatives have been visualized for decades, or centuries. However, the useful nature of this change is already being widely accepted, and there is hope that we will move towards genuine integration based on the study of real situations and problems of the entire natural and social environment.

Lastly, one must briefly examine the question of the level of schooling for which integration is suitable, and after which some kind of diversification or specialization may be introduced.

Ideally, the approach outlined here seems to be valid for, roughly, the first eight years of education; or, one might say, up to whatever level in a particular country, universal education is visualized - since the approach facilitates universalization and helps partly in generating human and material resources necessary for it, and for development in general.

On the other hand, at the tertiary level of either liberal education or professional and vocational studies such integrated science is obviously not required. But it is not implied that the concern for the prevailing and the practical should be given up or that the institutions should no more concern themselves with all round development. Naturally then it is the stage of secondary education where various kinds of transition will have to be tried; and it is the stage when the child begins to be able to benefit from formal, logical and systematic building up of conceptual chains of thought. A practical restraining factor is our own inexperience with decentralized curriculum making of the kind required, and the fact that teachers, mostly educated through narrow disciplines, are unable to deal with either the curricular material or the associated real situations and problems. It has to be mentioned here that tertiary training in narrow disciplines also creates many difficulties in setting up interdisciplinary research programmes. A foundation laid on the basis of integrated science at the school will surely lead to improvement in the quality of scientific research in our institutions. The manner in which we can approach an "integration" or "coordination" or "interdisciplinarity" in higher education is quite a subject in itself and I shall refrain from discussing it further here. I may mention that in India we are experimenting with full integration of "science" and "social science" as environmental studies in the first two years of schooling, and with integrated science in two spirals during the next six years of primary schooling, terminating in interlaced units which may be identified as the traditional disciplines during first two years of the secondary school. In higher secondary (for the age group 17-18), there is provision for diversified courses on academic and vocational sides - in form of credit and semester courses. We have undertaken a vast programme of in-service teacher orientation, and a programme of revision of pre-service courses. We have introduced "work experience" at all school levels, and we are experimenting with community involvement both in formal and non-formal education. Many experiments with university level courses are also being done.

In short, schools today are being opened up to wider social and scientific experiences in the interests of simultaneous spread of education and the priming of local development, through environment based integrated science education.

## 2.6a Where Have We Got To? Where Are We Going?

Judith Reay, University of the West Indies, St Augustine, Trinidad
(Conference Editor)

In this talk I intend to confine myself to some of the broad features of the Conference as they have struck me. It would not be appropriate in my treatment to refer too specifically to the working groups or plenary speakers, who have provided us with in-depth statements that need reflection, so I shall be touching on matters that have concerned all participants at this Conference. These are, of course, the concept of integrated science and the processes of integrated science education and international exchange in the context of the past and future.

Coming as it has a decade after the Varna Congress and half a decade after the Maryland Conference, the Nijmegen Conference on Integrated Science Education Worldwide is a significant landmark in our profession. However, a question that has exercised every participant is. has this conference and its predecessors, done any good, and will we as professionals adopt wiser practices in future?

At this Conference all participants have been reflecting on the last ten years, sharing their experiences, and looking ahead. If it were possible at this stage for any of us to identify really concrete outcomes of Nijmegen we would have been working at a superficial level. A schoolteacher friend of mine, thinking aloud at a meeting, recently postulated that one important purpose of practical work in science is to slow up the rate at which learning takes place. It allows time for the material to enter the cognitive structure of the learner, to become an integral part of him. Using the same principle, it seems to me that the discussions of Varna and Maryland are only now becoming coherent, and I expect the exchanges at Nijmegen to crystallize only after several years. Big understandings grow slowly, and this may be part of what Jim Rutherford had in mind when he advocated evolution instead of revolution in plenary lecture 2.4.

Integrated science is a concept, one that has been slowly taking root in the cognitive structure of each participant over ten years. Like all concepts, it is very personal, and it is no wonder that participants spent some time debating the meaning of the term (as was done at Varna and Maryland) without satisfying anyone. For each of us the concept is different. However, I should like to illustrate what integrated science means to some of the people I have been working with. There still seems to be a gap between examinations and the way teachers would like to teach (Working Group 4b made this point), so I have chosen my illustrations from some examination questions that have been suggested.

1. The first item is universal in terms of science, something that the Conference is agreed we must not sacrifice in our concern for social relevance.

You overhear four men having a discussion about the shape of the earth.

a. The Astronomer says he knows that the earth is nearly spherical, but flattened at the poles. He knows that is true because he took some measurements from the stars.

b. The Sailor says the earth is as round as a ball. He knows that is true because he sailed westwards and went on sailing that way until he ended up where he started from.

c. The Philosopher says he knows the earth is flat. He knows that is true because he read it in a lot of books.

d. The Astronaut says he knows the earth is pear-shaped. He knows that is true because he took a photographs on the way to the moon.

Each man produces his evidence so that you know he is not making it up.

Which man do you think has provided the best evidence? Give reasons for your opinion. Say why you think the evidence of the other three is not good enough.

Whether or not we use an example like this, which is not discipline-oriented, and is easier to devise than in the context of a discipline, we are more likely in 1978 to find that children can evaluate evidence, in contrast with the children who in 1971 said "The Astronomer is right because my social studies teacher told me so."

2. The second item would be treated in different ways by children in different social settings, perhaps within the same country.

In 1969 USA announced that it had landed men on the moon, and television pictures were flashed round the world. There were three main reactions from the public

a. a magnificent achievement of mankind

b. flying in the face of God

c. a typical propaganda swindle with fake TV pictures.

In each case give a respectful discussion of why people may have felt as they did, and give your own opinion.

This item mainly concerns itself with attitudes, but perhaps children should be more explicitly asked to use their scientific knowledge if we are to avoid the charge of forgetting that we are supposed to be teaching science.

3. The next item reveals that lions lurk in the path of integrated science teaching.

Discuss astronomy and astrology in terms of science and superstition.

I have put this issue to a number of colleagues, some of them at this Conference, and here are some of the reactions I have had.

a. (Barbadian) Astrology is superstition and children must be taught so from an early age.

b. (Trinidedian) A Large proportion of our population is Hindu. Science teachers have no right to intrude on beliefs and to come between mother and son.

c. (Indian Hindu) All superstition is dangerous; the scientist has a responsibility to eradicate it from our society. However, our means of indoctrination must be subtle. By teaching about science, and the science of astronomy, we can expose astrology as superstition without ever mentioning it.

d. (Indian Hindu) All indoctrination is wrong. Scientists are in danger of developing their own myths. How can we be sure that man has actually landed on the moon? Is the evidence any better than the evidence for reincarnation?

e. (Dutchman) That is a matter for religion and metaphysics. The Western European scientist ought not to attempt to handle that question.

Here we have an example of conflict of values. And it reminds us of Dr Terlouw's statement in plenary lecture 2.1 that science teachers bear a heavy responsibility, although he was speaking in a different context. It also reminds me of a statement by Mr B G Pitre, that I shall summarise as

$$dc/dt \gg ds/dt$$

where c is curriculum change and
s is social change.

4. The last example that I shall give is meant to illustrate that certain curricular elements that are needed in some countries would be quite out of place in other countries, indeed incomprehensible.

What would the following groups of people have to say about the burning of cane fields as a preparation for harvesting

- the scientists
- the sugar manufacturers
- the cane-cutters' union?

The practice of adopting curricula from other countries is long dead: and adaptation has slowly been giving way to the creation of new curricula, tailor-made for the local situation, as we science educators come to understand what integrated science can do for the children who are our responsibility. So much freshness has come out of Australia, Brazil and Israel.

I now come to another matter which has received a lot of attention at this conference, namely the so-called dichotomy between developed and developing countries. I am not at all sure how to distinguish between developed and developing countries. Are China, Egypt, India, Ireland, Israel, Malaysia and Malta developing countries or not? Some of these have the oldest civilisation in the world and I simply cannot accept that they are second class participants in the process of educational change. In Singapore I was told that a developing country is one which assembles transistor radios (thus Malaysia has now taken over the industry from Singapore) while the United Nations has provided the following definition

> For United Nations purposes a country is less developed if the country considers itself less developed and if it applies for economic assistance.

It is true that in terms of quantity of human and material resources, and quantity of education, there is a dichotomy. It is also true that the first science curriculum innovators were from the USA and UK, but we ought not to extrapolate from them to developed countries as a species. We have only to contrast the amount of innovation in integrated science education in countries like Fiji, Jamaica and Swaziland with what is going on in the same field in the Federal Republic of Germany and Argentina. The rest of the world has a lot to learn from the so-called developing countries; the Conference has provided one opportunity for this exchange, and perhaps the smaller countries have learned that they should be walking tall.

An international conference like this one can help us as individuals to refine and enrich our concepts of integrated science education much more than can a national or even a regional conference. It also helps us at the very material level by giving us ideas and materials for our day-to-day work. I should like to illustrate this with a few examples chosen from my own job as a teacher-educator. My class contains people with various kinds of science degrees, all with several years of postgraduate teaching experience, and all continuing to teach in their own schools during their professional training. Their very first experience at the beginning of the course is a learning programme called "Playing with the Woodlouse", designed to start teachers thinking about the processes of science. It was created by Cesar Quiros of PRONAMEC and I found it at Maryland. After two months, when the teachers are back in their schools, I provide them with a self-evaluation instrument drafted by Jay Lemke of the City University of New York - I also found this at Maryland. When Hubert Dyasi of SEPA sent me the draft of his paper for the Nijmegen Conference, I immediately had it reproduced for my students since it articulated so movingly all the objectives of my own course. Other materials in regular use come from over a dozen other places from Lebanon to the Philippines to New Zealand.

I have talked about some of the ways in which I think the Conference has been useful to individual participants. I should now like to consider whether there have been any large scale outcomes.

One of the features of the Nijmegen Conference has been the nature of the working group lead papers. The authors, already experts in their own fields, began their task by carefully researching the growing body of literature so that the discussions would go beyond the intuition of the groups. Then in all humility the authors posed sets of questions to which they needed answers. In general, they have been most excited about what the working groups gave them, drawing on collective wisdom and experience. All participants brought greater or lesser degrees of experience, but each experience was unique in a way which served to illuminate the discussions, and consequently to illuminate the final publication, New Trends in Integrated Science Teaching Volume 5, that will be read by many who have not been at the Conference. Working group authors and participants have reported that the various chairmen and rapporteurs carried out their arduous jobs with distinction.

Some participants felt that the Conference should have come up with a set of decisions. But how would that be useful or even possible? Stufflebeam has pointed out that in decision-making there are three elements

- the options
- information about the options
- one's own values.

All we have been able to do at this Conference has been to identify the options and to share information about the options. The final step towards decision-making must be taken by ourselves as individuals, by the educators with whom we work at home, and in the societies in which we work, according to our own values.

Our profession, especially in integrated science, is refining and developing itself. We at the Conference are standing on the shoulders of those who came before us. Since Varna, there have been Maryland, regional activities, four volumes of New Trends, numerous scholarly papers and much research, and at least 130 fully developed curricula (according to Sheila Haggis and Philip Adey in plenary lecture 2.2). Next year, 1979, is to be the Year of the Child. I do believe that our integrated science teaching will in the future be much more suited to our own children growing up in the 1980s than the dead knowledge that characterized our so-called science teaching in the days before Varna.

But I believe we should waste no time. Dr Terlouw showed that science and technology are powerful and dangerous forces in society, and that science teachers shape the future. There is so much more that children have to learn if they are even to survive in the next decade. It is my belief that significant progress is unlikely to occur without a commitment and a tremendous amount of work from science teachers' associations, working nationally, regionally and internationally. I am sure there is no other way.

I am sure you will agree that in the Nijmegen Conference something of value has been achieved by ICASE and NVON.

### 2.6b Where Have We Got To And Where Are We Going?

Professor Charles Taylor, University College, Cardiff
(Chairman: ICSU Committee on the Teaching of Science)

It is always an extraordinarily daunting task to attempt to summarise a dynamic and lively conference. I would first want to applaud the planners who opted for a small number of plenary sessions, concentrated at the beginning of the conference, and for which the choice of speakers and of topics was outstandingly well made. This left a great deal of time for the real work of the conference in digesting, criticising, augmenting and in some cases re-writing, the drafts of the working papers which were commissioned well in advance of the conference.

But the large amount of time given to the working group activity, the wide range of interests of the participants (over 260 people from about 60 countries and including teachers, teacher educators, educational administrators, and many others interested in science education) and the enthusiasm of participants, authors, chairmen, and rapporteurs, makes any straightforward summary quite impossible, and certainly such a summary would be unlikely to convey the real flavour of the meeting. The essential feature was that people met and talked and shared their experiences.

I am an academic physicist with a deep interest in science education, but with little real experience of teaching in the earlier years, or a wide experience of many countries. It might, however, be helpful that I stand a little apart and that I view the conference perhaps slightly more objectively, but I must emphasise that what I give here is a personal reflection on the deliberations of two very busy weeks.

Before starting on the conference itself it might be useful for me to explain a little of my attitude to integrated science, speaking as an academic physicist. I have always felt that the differences between the disciplines are not built-in; there is no God-given corpus of knowledge around which one can write 'physics', or 'chemistry', or 'music', or 'integrated science'. I am tempted to re-phrase a well-known remark as "Knowledge is born free and is everywhere in chains". The differences began to be codified in the late nineteenth century; but they really arise as differences of viewpoint between the scientists. In other words the significant thing is not that chemistry differs from physics, but that the chemist's view of the world differs from that of the physicist. One of my favourite cartoons which illustrates something of this theme in a slightly facetious way is of a small girl in a mime class who is pretending to be a tree. "Thought balloons" attached to her class mates show the wide range of different impressions that she has created, ranging from space rockets and armed robbery to ballet dancers and flowers.

I suppose that, ideally, I should like to see teaching in primary schools arranged so that children would not be conscious of the differences between science and other aspects of knowledge and would not really be aware of any fundamental difference between science and singing and between singing and story time. They should accept them all as part of life and of living and of our curiosity about the world about us. I was particularly fortunate during my secondary education to be uncertain whether I was taught physics by the music master or music by the physics master. It was the same person, and I was rather horrified later on to find that other schools were not so civilised! But we must be realistic. The whole paraphernalia of university departments, of professional bodies, and of learned societies is all based on well-defined and separated subjects. There is a well-known story about a man who was lost in a back street of a town and stopped a small boy to ask him the way to the town hall. His reply went like this: "Go in that direction and take the third on the right and then.....No, that won't do. Go in this direction and take the second on the left and then the first on the right and then.....No, that won't do either. You know if I were going to the town hall, I wouldn't start from here!" But we are here in 1978 with all the traditions and rigidities of the past and so we must start from here.

I suppose the 64000 dollar question which will be put to me as head of a physics department is "Would you take into your department a student who has been brought up on integrated science at school". And my answer is usually that I am more interested in the student's quality of thinking than in precisely what he knows and, given the motivation, it would not be difficult to compensate for any informational deficiencies.

Now to the conference itself. I have divided my remarks into two parts, corresponding to the two questions in the title of the paper. I have introduced a few rather flippant catch-phrases to summarise each point. (In the presentation at the conference these were revealed one by one on an overhead projector and the code letters at the end of each of the headings refer to the plenary lectures or working groups on which the items were based.)

Where have we got to and what are the messages that I seemed to be receiving during the conference?

The first, which was brought home by the first exhibit in the exhibition that we passed each morning on the way to the meetings and which also seems to be a recurring theme is summarised as

**PEOPLE MATTER**

In the context of this conference this perhaps should have special reference to children but not exclusively so. It is interesting to recall that almost twenty years ago Professor Hooykaas of the University of Amsterdam pointed out that science had been depersonalised for the last 100 years. One of his illustrations was that, in the 18th century, pictures in science textbooks showed the experimenter in full academic robes set in the laboratory amongst his apparatus. In the late 19th century the experimenter is reduced to a detached pair of hands. But in the first half of the 20th century even the hands disappear and the experiment seems to be performing itself. It is gratifying to have seen, both in the exhibition of project materials, and in current textbooks that the trend has now reversed again and people are back in the illustrations.

We heard reports of all the many projects on integrated science that have been developed around the world, especially in developing countries, and, in the second plenary lecture, 130 such projects were summarised, all of which have been developed since the Varna conference of ten years ago. So my next heading is

**INTEGRATED SCIENCE LIVES!** $P_3$, $W_2$, $W_3$*

and I am sure that it is on a very firm foundation.

The next message that seems to be coming over to me is that it is particularly appropriate and important to

**INTEGRATE EARLY** $P_2$, $P_6$, $W_{4a}$

and there was considerable agreement on this both in relation to science itself and to science with other areas of knowledge.

But one begins to find doubts creeping in as consideration of older age groups begins. I suspect that this is not for any intrinsic reason but rather because, as students get nearer to the point of departure from school - whether into higher education or directly into employment - teachers and administrators feel the need to conform more closely with tradition. If one could wave a magic wand and rewrite the history of 19th century science we might, even now, be at a conference discussing the desirability of splitting traditional integrated science and beginning to teach the sciences separately!

But whatever the reasons it seems clear that

**THE HIGHER, THE FEWER** $W_{4b}$ & c

---

*See Chapter 6 for Summary of Programme and Chapter 3 for Reports of Working Groups.

This is a British phrase originally used in relation to high finance - the higher the finance the fewer understand it. And it leads immediately to another question that has been asked implicitly and explicitly and to which a variety of answers were given.

### BUT IS IT RESPECTABLE? $P_4$, $P_5$, $W_{4b}$ & c

We have had most eloquent theoretical justifications (especially P4) but I have to admit some doubt about their validity. I tend to agree with James Rutherford (P5) that the case on paper is fairly well balanced for and against - though I must add that I did not agree with the whole of his talk. What matters to me is the purely pragmatic test. Are the children emerging from integrated science courses livelier, more motivated, more interested in scientific aspects of the world around them? Are the delightful curiosity and uninhibited questioning of the seven year olds - which so often seem to have been squeezed out by the age of thirteen or fourteen - better preserved? If the answer to these questions is "Yes" then for me integrated science is respectable. But I have a sneaking suspicion that, in the end, it is not the curriculum or the course plan that matters but the quality of the teaching.

Nevertheless one of the messages that has come across quite strongly in many discussions is that, if you are to 'sell' integrated science to your headmaster, your school authorities, your ministry, or some other body, you must not only have a well argued case for respectability, but you must also have a systematic approach. A complete package of outlines, materials, resources, costings, etc, is needed to show that you mean business. My phrase symbolising this is

### SYSTEM SPELLS SUCCESS $P_5$, $W_3$, $W_6$

That immediately raises the question of how one measures success. We devoted a good deal of time to this at the meeting in Oxford in 1975/6 and it has cropped up again many times in Nijmegen. I think we must agree that

### EVALUATION IS ESSENTIAL $P_5$, $W_5$

but I am bound to say as a practising scientist, that one can sometimes be misled by purely formal procedures. In science, intuition, the 'jump in the dark', plays quite a significant part, and the art of being a scientist is to be able to recognise whenyour results are leading you in the right direction and when they must be treated with caution. By all means let us apply evaluation procedures to our projects in science education, but let us also remember the importance of common sense in interpreting the results.

Many times during the conference we have heard of individual people working perhaps by themselves in a location that is remote from supporting agencies and feeling totally overwhelmed by the volume of words and paper that pours out from conferences, project organisers, publishers, ministries, etc. The cry for help - in whatever language - must be recognised and answered. Since we are in the Netherlands I have symbolised this with the phrase

### IS ER EEN DOKTER IN HET HUIS?

How do we respond? Many individual answers have been given, and on the whole, the scientific community is good at responding, though sometimes a little insensitive to the needs until attention is firmly drawn to them.

We have been told that Associations for Science Education are an Anglo-Saxon idea; this may be the case - but I think the idea is good. They do work remarkably well in giving non-governmental, non-hierarchical help and support to teachers. But once again we come back to the importance of personal relationships and I make no apology for rounding off the first part of the summary by returning to my first phrase

PEOPLE MATTER

This also provides the bridge to the second half of the conference concern "Where as we going?". At the beginning of the meeting Dr Jan Terlouw - a nuclear physicist turned member of parliament and leader of his party in the Dutch lower house - in a most impressive address (P2) warned that "Those who know the problem and still teach carry a heavy responsibility".

Teacher education was stressed; teachers were urged to become involved in project and curriculum development; science educators were urged to involve teachers at an early stage in the development of new programmes; teachers were urged to persuade their school authorities of the need for change in the approach to science. I feel therefore that the load being placed on teachers is a heavy one;

ITS TOUGH ON TEACHERS $P_2$, $P_5$

but what about the teachers who are just not interested in doing anything beyond the bare minimum of duty? The participants of the conference by their very presence demonstrated their interest and motivation. But in my area of the UK if we hold a meeting of teachers or an in-service training course we probably reach 20-30% of those within reasonable geographical distance. This might be thought reasonable except that it is always the same people who come. If the topic concerns a new examination syllabus the percentage might rise somewhat. But has anyone a solution to the problem of reaching the remainder? (I should hasten to add, lest I should be thought in any way over-critical of teachers - that precisely the same sort of phenomenon exists for university staff). We talked a great deal about in-service and other kinds of training but all such courses pre-suppose the interest of the teachers. I feel that more attention must be paid to the more difficult problem which I have symbolised by the phrase

WHAT MAKES TEACHERS TICK? $W_9$, $P_5$

In our debates on integration we have considered a number of possible themes that can be used to help the process; the environment, health and nutrition, agricultural and food problems, and many others figured explicitly in the groups. But we must be ready to take account of changes in fashion and not become too rigidly tied to one theme. At the moment the environment is "in", but already in Dr Terlouw's address we were warned of the dangers of thinking of environmental problems in isolation and to exclusion of other problems which can lead to agonising crises.

We must in other words remember that

FASHIONS FLUCTUATE $P_2$, $P_5$

Some years ago when we were planning the expansion of our college campus we considered the problem of new disciplines that grow out of combinations of existing ones and decided that because of the relative speed with which fashions change we should retain the more or less traditional departments as the basic units but provide mechanisms for grouping and re-grouping them from time to time as the need arose. We now have a flexible degree scheme which enables groups to be brought together under a board of studies to teach in a very integrated way but at the same time, if the fashion changes, we can very easily divide and recombine in a different way.

But in spite of this I would venture to predict that one element that is likely to remain for many years to come is

COMMUNITY CONTACT $P_2$, $P_6$, $W_{7a,b \& c}$, $W_{10}$

in some form or other. Many of the successful courses and projects that we looked at during the conference contain some relevance to the home, to the village or to the city, to industry or to world problems and I feel certain that this kind of relevance will continue. Incidentally, in considering the wider implications of the 'science and society' issue we must not forget the image of the scientist that the general public gleans through the media. In most films or television plays, if a scientist is involved, more often than not he is either a criminal lunatic or so eccentric as to be a figure of fun. The nice solid family man is always in advertising or insurance!

But to return to the conference deliberations, some considerable effort was expended on the relationships between subjects, including, of course, mathematics. This is an area where my interest as chairman of the ICSU Committee on Teaching of Science is particularly strong. In both groups and plenary sessions the question of language - both verbal and mathematical - as a barrier cropped up. Again Dr Terlouw referred to the probability that even two physicists at the research level might not understand each other's jargon unless they were in closely similar fields. Some jargon is inevitable - but it can arise from lasiness. Perhaps the right cautious word would be

MIND YOUR LANGUAGE! $W_8$

There are several ways of trying to bridge the gaps which are quite independent of integration. Commentaries on - or even translations of - a book on a specific topic by someone from another discipline provides one possible solution. My own International Union (Crystallography) has it in mind to produce a pamphlet designed to help other scientists to understand the jargon and symbols of crystallographic papers sufficiently to be able to gain information that is useful and also to be able to understand its limits of validity.

Is it possible to discern a single important result as a predictor for the future? For me it has been the spirit of cooperation, the feeling that people working together in their groups were really beginning to understand each other a little, to find that the problem of one individual was surprisingly similar to that of someone else in a totally different region of the world. There can be no single grand solution to the problem of educating our children in science. There is no one grand strategy that we can publish and say "That is what we achieved at Nijmegen". And it is right that that should be so and that we should go away not feeling that we have achieved something, but that we have gained the information, the support and the strength and enthusiasm to go back to our own sphere and achieve something there where it really matters.

I am very conscious that my remarks have been somewhat superficial but it may be that they have given something of the atmosphere of the conference. In my presentation on the last morning at Nijmegen I could not resist the temptation to perform one lecture demonstration before I finished. I referred to a simple experiment that I very often use when I am lecturing on relationships of physics and music. One of the important questions to be answered is why it is possible for the human ear-brain system to disentangle all the various separate pressure waves that are developed, for example, by each individual instrument in an orchestral performance. It is common knowledge that we can listen at will to the playing of any particular instrument and yet the mathematical problem of disentangling the separate components from the one combined pressure wave is formidable. One of the partial answers can be illustrated with a tuning fork. It is a familiar fact that the tuning fork on its own creates a very small sound, but if placed on a heavy table the sound can be heard very easily. In talking to young people about this experiment I suggest that the reason is that the tuning fork persuades the table to vibrate with it and hence increases very considerably the amplitude of the pressure waves that can be generated. But I also point out that the tuning fork cannot make the table vibrate instantly. There is an argument between the tuning fork - which is dynamic and lively but small - and the table which is static, heavy, lazy and full of inertia. If the tuning fork after being struck is placed very carefully onto the table one can actually hear this altercation as a different tone quality during the first quarter of a second before the fork settles down to a steady note. It is this altercation - technically known as the starting transient - that provides part of the secret to the solution of our problem. It occurs in all instruments, the reed argues with the pipe in woodwind instruments, the string argues with the body in the violin family, and so on. The argument is over in a tiny fraction of a second but it is so characteristic of a particular instrument that the brain recognises it and so is given a clue about the presence of the various individual parts of the vibration.

What has this got to do with integrated science? I suggest that the lonely person out in the field is something like the tiny tuning fork and the heavy table represents the mass of officialdom that they need to convince that change in science education is needed. There has to be an argument in order to get things moving but there are two important features that may be of comfort. The first is that the very argument itself marks the effort as something new and different and enables it to be recognised; the second is perhaps of slightly less scientific validity but provides a very comforting note on which to end and it is this

THE TUNING FORK ALWAYS WINS

# CHAPTER 3: Reports of Working Groups

## Working Group 1: Aims and Objectives of Integrated Science Education

Author: Mr N Booth

Chairman: Dr A Lucas. Rapporteurs: Mr E Hofs and Dr B Thomson

The working group agreed that there were few differences between the broad aims of integrated and discipline based science courses and that an integrated approach was the most appropriate technique for young children, and was suitable for junior secondary schools (12-15 or 16 years). There was less agreement concerning the appropriateness of integrated approaches for all science students in upper-secondary (16-18) and tertiary (18+) levels.

It was also agreed that, as it is not the major purpose of schools to produce highly trained specialists, the general goals of schooling were such as those listed on p.2 of the working paper. There was very strong agreement among delegates from developing countries that societal needs must be reflected in aims of science courses, which establish a link between cultural and economic growth, but the specific aims emphasised must reflect local needs. Some members from developed countries did not believe this applied to them, but others felt that the difference was in the degree of explicit emphasis on social aims.

The working group considered methods of ensuring that stated goals were attainable and agreed that when planning an integrated science curriculum the aims and objectives should focus on the needs of the pupil, although the teacher as a learner and the intergeneration factors between teacher and student must not be neglected. Process skills are important generalizable organising principles, and an integrated science curriculum allows the use of realistic problems relevant to the student. Chosen problems must be capable of presentation without distortion, remembering that although professional scientists may see a problem as extremely complex, a child may consider it adequately in a simpler way.

As well as encouraging the interest and curiosity of pupils, a carefully planned integrated science course is more likely than the separate disciplines to provide the coordinated multiple examples of a concept that increase its transfer.

In addition to the points mentioned above the following comments were made when considering the specific arguments, supporting integrated science (working paper p.5).

Argument a): This must be explored in more depth if it is to become a strong point. Argument c): Although most problems encountered outside the laboratory are multidisciplinary they need to be discussed in terms of pupils' capabilities, motivation and attitudes.

Argument d): The fact that integration has been going on for many years is not a sufficient argument for continuing it. Argument e): integrated science allows a more efficient and richer curriculum. Argument f): integration of the natural, social and behavioral sciences in a broad curriculum provides a realistic view of the place of science. The following additional comments were made when considering the specific points against integrated science listed on p.6 of the working paper. Argument a): Evaluation data are needed to compare the effectiveness of integrated and separate sciences. Argument c): there are techniques for assisting teachers adopt, and parents accept, an integrated science programme, but there may be difficulties in assisting employers recognise the value of integrated science. Argument d): the potential scientist need not be penalised in an integrated science curriculum, which can be planned for any specific ability group. (The working party did not discuss mixed ability grouping.) Argument e): although integrated science may facilitate communication by emphasising themes common to all disciplines, students should become aware that science does contain methodologically distinct disciplines at the research level. It was also emphasised that political, social and other difficulties in initiating major educational change vary from country to country.

### Contributed papers

The group examined objectives listed in the draft trends paper and in papers by Mr Marshall (UK) and Dr Ganguly (India). It was easy to agree with the various objectives due to their broad nature and concern for children. Many countries have lists of aims and objectives but the group reviewed only these three; the working paper did not synthesise or analyse the variety of objectives in different countries.

A paper by Dr ten Voorde provided a case study of an investigation of the possibility of introducing integrated science, in this case in the Netherlands.

Dr Al Rashidi argued for "Man" being the focal point of integrated science education and research programmes; many integrated natural science programmes now pay insufficient attention to man, and he argued that students must gain self-knowledge as well as learning about chemistry, physics, biology and the social sciences.

## Working Group 2: Design and Content of Integrated Science Courses:

Authors: Dr T Gadsden, Dr P Becht, Dr G Dawson.

Chairman: Winston King, Rapporteur: Roger M Garett.

In order to cover the wide range of the area under discussion the group was subdivided into two main sessions with three sub-groups in each session.

### Sub-group 1 Course objectives

Chairman: Jan Raat

Rapporteur: Isola Oyetola and F Arnold

Despite some initial confusion over defining the terms "aim", "goal" and "objective" it was generally agreed that aims were of a much broader character than objectives and consequently the group agreed that the five categories of objective types, viz those of:

a. Scientific literacy
b. Personal growth
c. Social relevance
d. General education

were useful as a guide to help organise the formulation of an all-embracing set of objectives.

It was also felt that possibly the more highly developed the system of integrated science teaching became the more detailed could objectives become within these aims.

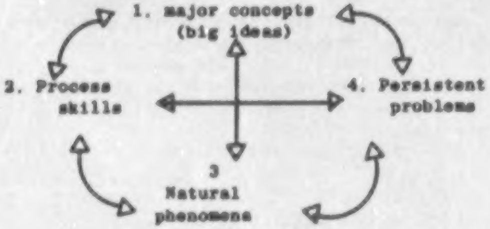
It was also felt that objectives should be formulated as far as possible by the classroom teacher and that there should be strong emphasis on this aspect in a teacher's training.

### Sub-group 2 Organisation and focus

Chairman: Evhan Uswyshyn

Rapporteur: Jan Hogeveen

When considering "focus" the following diagram was felt to be particularly appropriate for viewing science as a unified whole.



1 and 2 are organising themes related closely to disciplines

3 and 4 are organising themes related to the learners and their direct environment.

It was felt that a course could not be of the highest quality if it did not utilize all of these categories during the development process.

It was decided that the following factors should be taken into account when a group is developing an integrated science course.

1. The political system
2. The educational and examination system
3. The culture/religion of the region
4. Financial considerations
5. The overall goals for education of the country, state, school, etc
6. The social relevance to the learner or appropriateness of the content
7. Recommendations from professional organisations
8. The age range of the target population
9. Students' previous knowledge
10. The qualifications of teachers and the teacher-training facilities available
11. Laboratory and back-up facilities in the schools
12. Expertise of the curriculum developers both educational and scientific, their knowledge-gleaning theories, etc.

## Sub-group 3: Course organisation and content

Chairman: George O Dawson

Rapporteur: D A Black and Terry Grier

Considerable time was addressed to the issue of identifying a basic core of material that can be taught in an integrated form. These discussions involved problems of evaluation, the means of selecting the teaching/integrating technique to be employed, the need for a broader base of decision makers and the problems of pre- and in- service teacher training.

Some tentative answers to these problems were made but cannot be regarded as guidelines.

The content of a course must be different for each country; however it must be decided by government agencies, working together with teachers, scientists and others involved and affected by the educational process.

A trend was noted in the content of courses towards more science being taught in primary schools and a much wider scope of science being offered at all levels. The general movement is probably from the academic outlook of the 1960s to the daily relevance of science that has characterised courses during the 70s; and the problem that faces curriculum developers is now to maintain an acceptable balance between these two extremes.

Further to this, three other types of guiding techniques were suggested by Haas.

1. Problem Solving

    a. Academic: to produce a broadening and deepening of knowledge. (The traditional "Scientific method")

    b. Technological: for an optimization or application of science content learned to related fields

    c. Political decision making: whereby judgements are made based on factual information and extended to real life situations.

A special point was raised here: is there transfer of problem solving skills to everyday situations?

2. Content via activities

The mode of instruction should be varied to maintain a high level of student motivation.

3. Decision making

The following model was felt to show useful needs.

National ) Objectives
Local )     > Programme - content.
Student ) Goals
Teacher )

A strong need was seen for a much more responsive mechanism to be constructed between teachers, curriculum developers, examiners, scientists, parents and ministries of education.

As far as the very important problem of teacher competence was concerned it was felt that strong statements relating to the retraining were required and that this should cover the initial training, retraining and in-service training which should comprise a balanced background of methodology and integrated science content.

If the development and modification of programmes goes hand-in-hand with the retraining of teachers, then the teachers themselves will feel involved in the production of new schemes.

Thus if teachers are deeply involved in the development of the materials, training will occur simultaneously with the production of these materials.

To this end a system of teacher disseminated schemes could be devised whereby a core of retrained teachers worked with small groups of teachers in a region who in turn retrained groups in different areas.

### Sub-group 4 Philosophical/psychological foundations

Chairman: J Raat

Rapporteur: P Arnold N Massey

The group discussed two main questions: which learning theories are the most valuable in organising integrated science courses; and how can these theories be used most effectively?

The work of such theorists as Piaget, Gagné, Vygotsky, Garperin, Ausubel, Davidson, Zarkov, Krog Claus were all considered, and it was felt that probably a blend of these ideas would finally have to be made although how this could be done at the present state of knowledge was not easy to see.

Certainly it was the concensus of the group that it is increasingly important for detailed consideration to be given to the work of both philosophers and psychologists before planning any curriculum development.

However, no psychological theory is a general theory about teaching and learning, and there are no clinical forms available as sources from which curricula can be developed easily. They are on too high a level of abstraction to be useful for teachers and curriculum developers.

It is necessary to train both teachers and developers, perhaps in a different way, so that they can use these theories as a source of inspiration. It is also necessary to provide support resources.

Consideration has been given to the fact that psychological theories are not the only source from the field of psychology, needed in the development of curricula. Investigations have to be made about the way we develop and use a language to describe concrete things, events, experience and concepts.

To investigate if a new curriculum is a better one new tools have to be invented, especially including the use of language, for the tools we have now are mostly very limited in scope.

### Sub-group 5 Articulation

Chairman: Evhan Uswyshyn

Rapporteur: D Cox

Articulation was defined as the planning and coordinating of the science and other school learning experiences so as to optimize learner progress towards achieving educational objectives.

Four models for articulation were considered viable

1. Concept. Key concepts are identified, and learning activities of increasing diversity organised around them throughout the programme

2. Topic (content) or syllabus

3. Topic + objectives (Activities may be listed as well)

4. Programme objectives: Science programme objectives are used to select the "organising themes" and activities at each level of the programme; the learning objectives for the "theme" reflect the level of sophistication of the learners, local constraints etc, as learners move through the programme.

These models can provide for both horizontal and vertical articulation although vertical articulation is possibly more demanding than the horizontal. The following points were also noted:

a. Teacher involvement is crucial

b. Moving from a discipline-orientated approach to integrated science is in itself articulation

c. Articulation must be given emphasis in the training of teachers, and curriculum specialists (decision-makers)

d. Facilities have an important impact in the specifics of articulation

e. Money and time for teacher involvement must be available

f. The language, maths and humanities programmes etc must be taken into consideration

g. Every reasonable consideration should be given to the problems of the student entering or leaving the integrated programme where populations are mobile.

## Sub-group 6 Development Process

Chairman: George Dawson

Rapporteur: D A Black and Terry Grier

It was very strongly felt that as many people, and as wide a range of expertise, as possible should be involved in any curriculum development process.

In particular it was felt that teachers should be given time off from the classroom in order to work in such projects. It was also suggested that a particularly fertile source of ideas would be found in a science teachers' association and that this would be a useful means of getting the right personnel for the job.

Once again it was emphasized that teachers need to be retrained in the methodology and content of Integrated Science.

Finally it was felt that the initiation of any scheme should be "grass roots" and come from the teachers themselves and that they should be involved at all times during any subsequent development.

## Working Group 3: Education of Teachers of Integrated Science

Authors: Dr N van de Cingel and Dr Y S Cheong

Chairman: Mr P Richmond. Rapporteur Dr A D Turner

Introduction Four areas for discussion were identified; three were considered by sub-groups 3.1-3.3 while the fourth was discussed by the whole group at the end of the working period.

Considerable time was spent identifying the common ground of I.S. in order to generate recommendations of value to all. The training of teachers and teacher educators was considered together (see 4).

This report considers general professional attributes (1), scientific attributes (2), resources (3), guidelines for the future (4).

### 1. Professional knowledge, skills, attitudes required by an I.S. teacher

1.1 Attitudes were a persistent theme of discussions; the teacher must look beyond the confines of scientific content. This requires an adjustment of attitude. The teacher should understand the interests, culture, language and values of the pupil. The environment is a resource and common ground with the pupil. The teacher must be helped to acquire economic, political and agricultural sensitivity in relation to scientific activity. The I.S. teacher might be required to discuss the notion of 'quality of life' eg in relation to decision making in the resolution of persistent human problems.

1.2 Teaching style It is important for the teacher of I.S. to develop a non-defensive teaching style to facilitate inter-disciplinary activities with colleagues and to gain cooperation from pupils. Team-teaching is one example of preferred style; the encouragement of criticism from colleagues and pupils in another aspect of that style.

1.3 Special competencies The teacher should be

1. Given the skills necessary to make a sensible selection of content (problems/tasks) which match the skills, interests and abilities of pupils. The contribution of learning theory and theories of development were thought important here.

2. A good manager of resources, eg able to recognise the potential of existing aids.

1.4 Teacher background is specially important. Knowledge and/or experience of alternative employment was thought valuable, as is his own teaching exposure, ie as a student.

### 2. Professional knowledge, skills and background of science required by an I.S. teacher

2.1 A model for the education of teachers of I.S. is based on the assumptions:

2.1.1 Teaching fundamental science, with concepts, models and processes developed by scientists in each discipline.

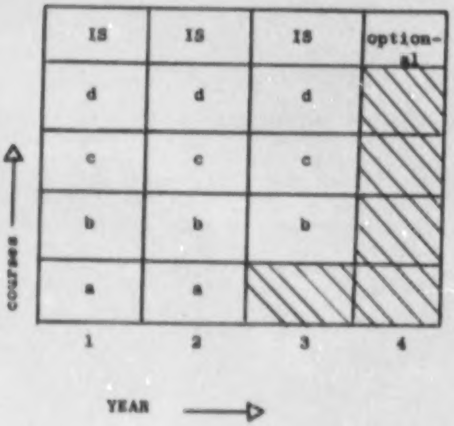
2.1.2 Teaching integrated science deals with the unity of the Universe and how man interprets what he sees.

2.1.3 Traditional university courses produce 'disintegrated' scientists, ie people who perceive the parts but not the whole. They are not suitably adapted to train teachers of I.S.

2.1.4 Prospective I.S. teachers in pre-service training should receive training in the basic concepts, models and processes of the various disciplines.

2.1.5 Teachers must experience the same problems as pupils in respect of, eg open-ended problems, decision making etc......

2.2 A model for teacher education over four years might be as shown.



| | | | | |
|---|---|---|---|---|
| courses | IS | IS | IS | optional |
| | d | d | d | ▨ |
| | c | c | c | ▨ |
| | b | b | b | ▨ |
| | a | a | ▨ | ▨ |
| YEAR | 1 | 2 | 3 | 4 |

a.b.c. - courses in basic sciences.

d. - A basic science or an I.S. Course.

I.S.- Integrated science.

▨ - Education component.

Such a model might be helpful in the designing of training courses. The course contains at least 3 one-year units in I.S. It might start with courses in basic science and contain education elements throughout. The final unit(s) might be flexible, either basic or I.S. to meet the requirement of the student. The best possible structure of the science element might be to group the knowledge around universal themes, eg change, energy, equilibrium, entropy etc...

2.3 In-service training should be related to the school science curriculum. It should be pitched at the appropriate level of the teacher. The quality and nature of the school course might be improved by the teacher undertaking critical studies of the course. An in-service course should offer a variety of methods and content to up-grade the teacher.

The group emphasised that converting subject specialist teachers was difficult and, in the long run, an inadequate method of achieving a supply of competent I.S. teachers.

## 3. Programmes, courses and materials for the education of teachers of I.S

3.1 Recently developed schemes for pre- and in-service training. Three schemes were outlined. Details of each appear in appendix 2.

1. A course for trainee teachers preparing to teach grades kindergarten to Grade 6 (USA)

2. In-service course designed to detach teachers from dependence on curricula and resource materials (Peru)

3. An in-service course for specialist teachers offering interdisciplinary studies (Mexico). Concerns health education. Independent University of Mexico.

## 3.2 Issues relating to the design of new programmes and courses

3.2.1 The transfer of objectives of training to the school situation. The possibility of in-service training of administrators, to inform them and to influence their attitudes to humanistic problem-centred approaches was suggested. The closer association of training procedures with curricula used in schools is desirable. Two implications for the design of teacher-training courses were noted.

Where centrally-directed curricula are used, training might focus more on encouraging students to clarify their understanding of objectives. Also on developing skills of applying a particular pedagogic model, such as 'objectives ⟶ process ⟶ evaluation'.

In situations allowing more flexibility, greater emphasis might be placed on students' ability to design curricula and to be adaptable to a variety of teaching situations.

Irrespective of the nature of the educational organisation it was thought important to concentrate on developing ability to apply the scientific process in learning situations; also to develop pedagogic skills not 'tips for teachers'.

3.2.2 Introducing the social relevance of science into training courses. For the purpose of discussion this was defined as 'concern for the organisation and function of society, and its well being'. Two examples were given, the PRONAMEC and FUSE approaches.

Seeking to expand teacher educators' own knowledge and skills was seen also to be important. Although social scientists might be usefully involved to a greater extent in training courses, there is no substitute for personal experience.

3.2.3 Desirable characteristics of teacher education programmes. Training courses might usefully include material which encourages students to recognise others' points of view, their own strengths and weaknesses and the attitudes in themselves which prevent open discussion of issues. The value of research into aspects of disposition such as attitudinal influences, on a world-wide basis was recommended to see in what way traits, such as adaptability, are culturally influenced.

3.2.4 The development of materials for use in pre- and in-service training. Three schemes were discussed in detail (see appendix 2, items 1, 4, 5). Particular problems arise in countries where some students may teach in impoverished conditions while others need immediate knowledge of how to use a range of resources and apparatus. It was felt that all students should experience a sufficient range to counteract the situation of schools receiving materials through overseas aid, which they had not met in training and which had no clear objectives associated with them and thus remained unused in schools.

## 4. Guidelines for the future development of methods and materials for training teachers of integrated science and for the education of teacher trainers

A dominant theme identified as a pattern for the future is the greater interaction of school, student and teacher trainer. Work in the field of alternative technology (UK) was used as an example. The after-care of newly-trained teachers was seen as both a cooperative venture and a necessity for the proper development of the teacher. The Schools Council Project 'Home Economics in the Middle Years' (UK) and PRONAMEC (Peru) illustrate possible ways of doing this.

4.1 For the teacher, emphasis will need to be placed on:

1. The art of managing large classes and mixed-ability groups.
2. The need to be capable of improvising equipment and activities.
3. An awareness of the impact of university style science courses on the student's view of science and of teaching science.
4. A recognition of the low level of competence of the newly qualified teacher and of the need to provide further support and training.
5. The role of external agencies in raising that level of competence, eg teachers' centres.
6. The integration of content and method in training programmes.

4.2 The role of the teacher educator might be improved by recognising the need to involve the school more in the training process. The training must be more school-based. In addition the teacher educator might profitably

1. adopt roles more in sympathy with the role he suggests for the teacher
2. recognise the value of the pupil-teacher relationship as a source of instruction
3. look to other professions for alternative models of training new recruits at the internship (induction) level
4. become more involved in in-service work, particularly after-care of the newly-qualified teacher
5. develop more resources for teacher education; the STEP and ASTEP materials were noted. Individualised instruction programmes were suggested as a promising target for development
6. Recognise the need for more experience of the community into which the teacher will be placed.

## Working Group 4a: Strategies for implementation of Integrated Science Education at the Primary Level

Author: Dr W Harlen

Chairman: Mr J Reeves. Rapporteur: Mr R Douglass.

Dr Harlen gave an overview of her paper and suggested that it could be conveniently discussed under four headings as follows:

- The nature and the special problems of science in the context of primary education.
- What is meant by implementation and related words, and how implementation strategies can be described.
- The advantages and disadvantages of various approaches and implementation.
- The possibilities of suggesting approaches most likely to succeed in various types of educational structures in different countries.

In her paper Dr Harlen raised a number of questions to which some answers were attempted.

1. Should we wait until teachers are well prepared to teach before we start science programmes?

Participants felt that

1.1 Children who started science at 12 are disadvantaged in later courses.

1.2 Science should be started even though its full goals in relation to the total education of young children may not be realised in the short term.

2. What type of science should be taught in the primary school? Is primary science truly integrated? It was felt that

2.1 Science at this stage should be undifferentiated and should be positively called "science" rather than "integrated science", "general science", or "nature study".

2.2 We should use content relevant both to the child's development and his environment to develop and emphasise science processes through which basic concepts should be formed.

3. How could we convince teachers of the value of spending time on science? The group thought that:

3.1 There should be more cooperation and sympathy for teachers from the education authorities, principals of schools and other educational institutions.

3.2 Classroom teachers should be involved in the development and implementation process where possible.

3.3 The valuable motivating factor of child curiosity can be used to develop scientific skills more easily than in the other subjects.

3.4 The developers of primary school curricula should be convinced of the importance of including science in the curriculum.

3.5 There should be continuous coordination with other primary school curriculum developers.

4. Who else besides educationists should be consulted and informed about the nature and content of primary science?

It was agreed that the following people should be consulted and informed

4.1 Resource personnel including research scientists.

4.2 Parents, through the media and by means of personal contact at science fairs, open days etc.

4.3 Other curriculum developers at the same level.

5. Can science be taught effectively in the traditional manner?

Participants agreed that

the sole use of traditional teaching methods was inappropriate to the science education of young children, but acknowledged that traditional methods could evolve into a more diverse methodology. It was emphasised that whereas an open methodology is important, the exclusive use of any one teaching mode is not desirable.

6. How can primary teachers with a poor background in science be helped to teach science?

The group believed that teachers had much more knowledge relevant to teaching science than they thought they had, and it is the duty of the curriculum developers to help them both to realise this and to gain the necessary confidence to utilise, and improve, their skills and knowledge through retraining programmes.

7. What can be done to minimise the adverse effects of shortage of materials and large classes?

Participants agreed to the following

7.1 The use of local materials, and bits and pieces brought in by the children.

7.2 The setting up of resource centres where teachers and parents could make simple and inexpensive apparatus with some guidance.

7.3 Seeking the assistance of the industrial arts and other departments and resources.

7.4 That teachers should receive assistance in the design and manufacture of materials.

7.5 That there should be a science table where children can display things they have collected.

7.6 That large class constraints can be reduced if teachers incorporate science activities for some children within existing activity periods for the whole class.

8. Strategies for implementation.

8.1 Strategy 1. Distribution of materials only.

The following disadvantages were added

1. The instructions may not be read or carried out.

2. Some teachers may stick too rigidly to the instructions and wrongly emphasise the lesson.

3. Some teachers may feel the need for making adjustments to the materials, but because of their background in an authoritarian situation may not feel able to do so.

4. Communication is only one way.

8.2 Strategy 2. Presentation of teaching materials through courses.

It was agreed that such courses should include retraining of teachers to develop desirable attitudes.

8.3 Strategy 3. The creation of multiple centres.

This strategy which involves the use of intermediate teacher trainers to distribute materials, help teachers in the classroom, and provide feedback to the curriculum development centre was strongly supported.

8.4 Strategy 4. Teacher Education.

It was felt that teacher educators in the teachers' colleges should acquire the following skills:

1. Appropriate questioning techniques both for teaching teachers how to question and encouraging children to ask questions.

2. Assessing their own effectiveness.

3. Improvising equipment from local materials.

4. Relating with the children directly in the schools in order to assist teachers to acquire this skill.

Participants also agreed that:

1. teacher educators should be involved in producing teacher training materials,

2. both pre-service and in-service training should be equally emphasised in the implementation process,

3. science should be made compulsory in the teachrs' colleges.

Dr Wynne Harlen wishes to thank Dr Peter van Summeren and Miss Arca for their helpful written contribution.

## Working Group 4b: Strategies and Implementation of Integrated Science Education at the Secondary Level

Author: Mr E Lambert

Chairman: Dr G Za'rour. Rapporteur: Mr J Hockman

The group of 25 members representing 14 countries agreed upon the following general principles:

1. The diversity of schemes of integrated science and of educational systems make it difficult to propose simple, widely applicable strategies for the introduction and implementation of integrated science.

2. There needs to be an initial commitment on the part of a group of educators and/or on the part of responsible officials about the worth of integrated science and the desirability of introducing it.

3. Chances of successful implementation of integrated science are higher when it is given a status equal to that of any other science subject.

4. Efforts should be made to secure acceptability of integrated science courses by universities and other tertiary level institutions.

5. Acceptability of integrated science will be enhanced if the needs of the community are taken into consideration when the content is selected.

6. In school systems where secondary students branch off into scientific and literary sections, the latter should be provided with integrated science as a better means of achieving scientific literacy than the study of one of the traditional science disciplines.

7. When formal education ceases at the lower secondary level, integrated science is seen as the best path to scientific literacy.

8. International, regional and national conferences as well as professional journals can be used as a platform for disseminating information about integrated science.

9. International organisations should publicise information about integrated science courses.

10. It is of vital importance to involve teachers in the whole process of curriculum development.

11. If relevant, efforts should be made to establish close cooperation between examining bodies and those involved in the development and implementation of integrated science curricula.

12. Support systems - in-service training, workshops, teachers' guides as well as pre-service teacher training - should be utilized in the process of implementation.

13. Team teaching can be helpful in the initial stages of introducing integrated science.

## Working Group 4c: Strategies and Implementation of Integrated Science Education at the Post-Secondary level and the transition from school to higher level.

Author/Chairman: Professor P J Fensham

Rapporteur: Professor C Singh

The group comprised 8 participants from 7 countries and although small represented a wide cross-section of interests and professions.

The group began by sharing their background and interest in the topic as a whole. It noted that integrated science was being taught in primary and lower secondary levels in schools. It agreed that there was a need for an extension of an integrated approach to science education at the post-secondary level but felt that there would be opposition to this move. It was therefore necessary to keep in mind the social forces in particular situations which are likely to be exerted by specialist pressure groups with vested interests in maintaining the status quo. Hence a strong case will have to be made to convince the opponents of the wisdom of such moves by their usefulness rather than presenting a general case.

Accordingly the group considered that integrated science could or is serving the following categories: (i) students of applied science and technology (ii) vocational students (iii) non-science (liberal arts) students (iv) students in interdisciplinary fields (v) students preparing for primary teaching (vi) students preparing for secondary teaching. The kind of integrated science courses will vary with the different needs of these categories but they are all likely to be characterised by being a study of science that directly relates to the real-life situations these students will face in their vocations or as citizens. For example a course for category (iii) would emphasise the unity of science as it reveals itself in real-life experiences. Again for those in category (i) the course would bring together the disciplinary contributions in an integrated manner to enable the natural phenomena on problem areas to be understood as a whole.

The group noted with great interest the introduction of integrated science to medical students in Mexico as a result of a conviction there that the students will find it easier both to comprehend and inter-relate the science knowledge in their courses to their ultimate medical practice. In many cases it would be desirable to take into account the social and ethical implications.

The group found it helpful to consider two possibilities for teaching science and its applications. A science course can be taught by going through a sequence of topics and concepts followed by examples of their applications. However, the content of such courses will not be the same as the course which starts with an application eg photography or refrigeration and then teaches the relevant science. It is the latter, the application centred approach, that seems to be more appropriate for planning the content of many integrated science courses.

The group in no way is suggesting that all science in higher education should be taught in an integrated way. Where the aim is to produce specialist scientists or to simply study a science in depth, it is obvious that single disciplinary study is necessary.

The group recognised a number of problems that are likely to arise when integrated science teaching exists on either side of the transition from school to higher education. Among these there are likely to be a claim by specialist scientists in higher education that students who have previously studied integrated science could have gaps in their knowledge and skills. Such students on the other hand may find specialist courses in higher education rather narrow and irrelevant. Students whose secondary schooling has been in one or two separate disciplines of science may feel a lack of confidence when confronted with a more integrated approach in higher education. The group was aware that integrated science courses are not necessarily another panacea. They could be as inadequate to the needs of their students as specialist science courses.

Finally the group turned its attention to a number of strategies for teaching integrated science in higher education. Of obvious usefulness are strategies that involve real-life problems and situations. Project work can provide natural links between scientific learning and the outside world. Various types of curriculum packages are available which teachers can use to provide learning experiences about real-life situations which would otherwise be inaccessible on account of expense, danger, time or ethical grounds. Examples of these could include simulation games, computer-assisted learning and the use of material (such as Bronowski's film series, 'The Ascent of Man') produced for other purposes.

It was recognised that science education at this level can learn from practices in existence in technological education.

Although the group was small, it nevertheless was aware of some significant examples of integrated science courses but felt that many more examples exist and an effort ought to be made to collate such information. Accordingly the group recommends to the Unesco Science Teaching Division to undertake the collection and dissemination of examples of such science teaching in higher education.

### Working Group 5: Evaluation of Integrated Science

Author: Dr S T Bajah. Chairman: Dr N Sabar.

Rapporteur: Dr M Rosier.

1. For the purposes of this working group, evaluation was defined as the process of obtaining information for decision-making.

2 Several types of evaluation relating to integrated science were identified; for example, of a curriculum project and within a curriculum project.

3. In the evaluation of an integrated science curriculum project, there are usually four stages: (a) needs assessment (b) programme planning (c) formative evaluation (d) summative evaluation. At each stage it is necessary to identify (a) a decision area, together with relevant decision-makers (b) informational needs to illuminate the decision areas (c) evaluation procedures to be employed to obtain the information. The stages do not represent an inflexible sequence, and there should be feedback to earlier stages. In particular, the summative stage of one project or part of a project may represent the planning stage of subsequent developments.

4. Evaluation of a curriculum project will often be geared to the stated objectives of the project. However, the evaluation may focus on criteria that are implicit in the project even though they may not be explicitly

stated. The evaluation may also examine outcomes of the project which were not included among the specified outcomes by the persons who designed the original project; for example, goal-free evaluation or evaluation linked to wider national objectives.

5. Caution should be exercised in attempting to evaluate the outcomes of a curriculum project at an inappropriate stage. Otherwise, the evaluation is likely to be confounded by factors associated with the stage of maturity of the project; for example, lack of teaching materials, or teachers with little experience of the project.

6. Evaluation need not necessarily involve statistical analysis. The extent to which statistical analysis is employed will depend on various factors, including the scale of the evaluation and the nature of the decision. For example, results from subjective observation of classroom processes and from objective structured student or teacher questionnaires may complement and illuminate each other.

7. It is suggested that the person(s) selected as evaluators should be associated with development from an early stage. As a result, the evaluator can often perform an important role in assisting in the classification of project aims and objectives. Evaluators appointed by agencies external to the project often represent a threat to the project staff, or to teachers in schools where materials are being tested. As far as possible, the evaluation should support teachers in the introduction of integrated science. This has implications for the procedures employed for both the trial-testing of materials and other evaluative functions.

8. In particular, some evaluation should be directed toward special objectives and characteristics of integrated science:

a. intentions: for example, scope and intensity of integration

b. transactions: for example, use of activity method

c. outcomes: for example, interdisciplinary approach to problem-solving, holistic understanding of scientific concepts and the application of scientific processes, and positive attitudes to and interest in science.

9. Given the importance of the role of the teacher within integrated science programmes, special attention should be given to evaluation relating to the teachers involved in a programme; for example, their training, their suitability, the support they are given, and the extent of their participation in curriculum development.

10. The time available to the working group did not permit the detailed discussion of all the above points, nor the detailed consideration of evaluation procedures.

## Working Group 6: Resources for Science

Author: Dr R Ferreyra. Chairman: Dr D Barlex

Rapporteur: Mrs M Kanya.

1. The following diagram was produced to show the jobs/roles of the members of the working group and the complex network of relationships involved in resource production:

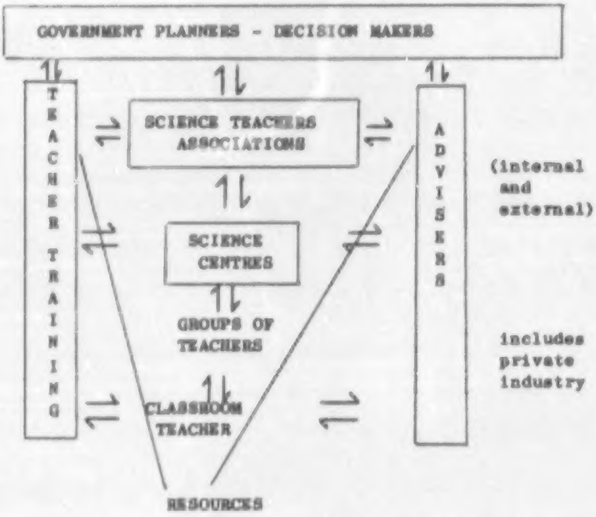

GOVERNMENT PLANNERS - DECISION MAKERS
TEACHER TRAINING
SCIENCE TEACHERS ASSOCIATIONS
ADVISERS
(internal and external)
SCIENCE CENTRES
GROUPS OF TEACHERS
CLASSROOM TEACHER
includes private industry
RESOURCES

FIG 1

Within the working group there was at least one person who is involved in the relationships signified by each of the ⇌ signs. (This sign indicates a dynamic equilibrium and the relationship pattern is seen as one which is NOT static.)

2. Moving on from this picture of the groups "roles", members of the group were asked to specify the following:

a. the operations they carry on in doing their job;

b. the resources they have found useful in carrying out each of these operations;

c. the resources they would like to have had access to (but did not) in performing each of these operations.

3. Discussion of these operation resource relationships led the group to identify three resources which were of overriding importance to the implementation of integrated curricula in developing countries:

I. An indexing of all the integrated science curriculum projects in existence each with a profile of its main features; to a large extent along the lines suggested by Haggis and Adey, plus the aims and objectives, topic headings and social problems reflected within and tackled by the curriculum together with information concerning the capital expenditure in setting up the curriculum AND the running costs of the curriculum.

The availability of such a card index system would enable advisers in the field to assess rapidly the usefulness of any number of existing projects to the curriculum requirements of their client. (The need to update this resource regularly was perceived.)

II. An equipment index concentrating upon improvised, low cost equipment giving detailed information concerning prototype construction by means of photograph/line drawings with dimensions, construction materials and operational limitations. This information index should be in sheet form which would allow easy extraction of details (for example) of simple balances (say 4 or 5 sheets) and rapid delivery by mail to where this information was needed. In this way the dissemination problems encountered with large manuals could be overcome.

a. The group felt that this resource needs the committed backing of UNESCO in the form of a definite full time appointment. It was felt that there was a tremendous amount of very valuable information "locked up" within the developing countries on this subject but, at present, no way of collating and distributing this information. The card index could overcome this problem.

A further suggestion was to try and make available assessments of commercially made equipment on a wider basis.

The role of science teacher associations in this matter was discussed.

b. In particular the information produced by NSTA - science materials and apparatus review committee - was quoted.

These resources would facilitate quick effective decision-making in schools concerning the construction and purchase of equipment.

III. At the government-planning level it was felt that the production of a "curriculum implementation guide" would be of immense value to hard-pressed Ministry of Education officials. This should be designed to allow decision makers to evaluate quickly and to see clearly the implications of a curriculum development project in the full context of its requirements eg initial capital outlay, annual running costs, teacher training programmes etc.

It is very important that such a guide does not take the form of a large, difficult-to-read manual. Examples of the use to which such a guide might be put are:

a. construction of an equipment purchasing programme and (b) setting up costing programmes.

The group then considered the network of communication that is in existence and where the resources outlined above and others would be implemented in such a network. As a model the following was set up - the overall direction of the arrows towards the classroom teacher reflects the groups' feeling that his needs in the world-wide view should not be forgotten.

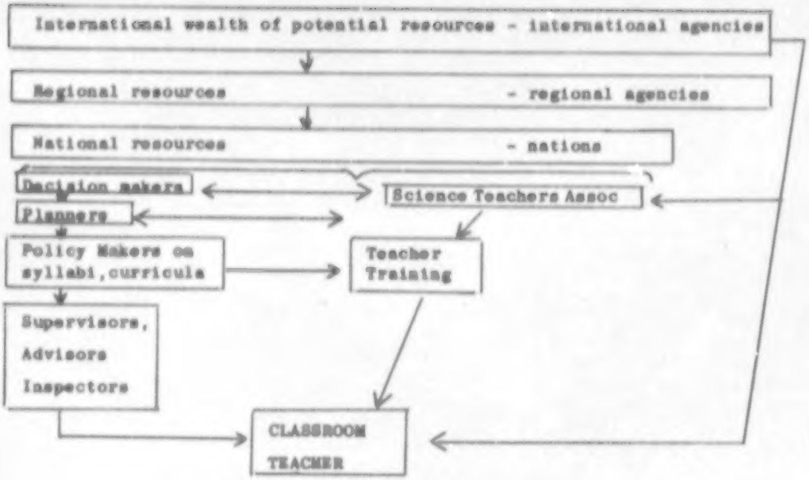

International wealth of potential resources - international agencies
Regional resources - regional agencies
National resources - nations
Decision makers
Planners
Science Teachers Assoc
Policy Makers on syllabi, curricula
Teacher Training
Supervisors, Advisors Inspectors
CLASSROOM TEACHER

FIG 2

It is noteworthy that the resources discussed in the first part of the report fit into this network at national resource communication level.

Discussion took place concerning the ease/difficulty experienced by a resource in reaching its target. It was the national/regional interface where most difficulty was encountered. The very central role of a science teachers association (STA) in its ability to communicate with decision makers, planners, teacher trainers, international agencies and the classroom teacher, and its ability to be used as a resource communicating agent, becomes very clear. It was felt that a low overall expertise in a nation's teachers was not necessarily a barrier to the formation of an effective STA as a few dynamic, well trained teachers could instigate and maintain the necessary organisation.

The discussion of international agencies centred on the World Bank. Its ability to control the equipment available to a developing country led to the concept of resource blockage points. The following emerged:

a. General - the ignorance of many countries concerning the aid that is available from international agencies.

b. Equipment/apparatus

  i. the docks, simply lost in transit

  ii. diversion into sectors of the economy for which they were not intended

  iii. lack of adequate instructions for equipment leading to its non-use

  iv. Government policy that "teachers pay for breakages" leads to equipment being locked away

  v. supply of inappropriate equipment - too sophisticated, therefore not used.

vi. The separation of pieces of apparatus and subsequent delivery to different schools when the pieces of apparatus need to be used in conjunction with one another.

c. Information - the communication schemes set up by some governments does not include private schools which, in some cases, form a large part of the education system.

d. It was pointed out that the World Bank had laid down the following requirements from a client nation before any materials/equipment are delivered:

a. There is a specified receiving and distribution procedure.

b. Equipment must be accompanied by instructions in the local language.

c. Training programmes in the use of the material must already be in existence.

d. Consumable items essential for the curriculum project must be included in the purchasing programme.

e. Technician/repair facilities must be available on a long term basis.

It is worth noting that even with these safeguards things can still go wrong, eg no budget allocation for storage facilities, thus even with a receiving/distributing procedure goods can still be badly damaged. The discussion then focused on the problems facing the classroom teacher and the resources he needed. The following emerged:

Demonstrations and associated equipment

The large class, low budget situation in many developing country classrooms focused attention on the importance of good demonstrations and the provision of comprehensive demonstration kits. The implications for teacher trainers and resource providers should be obvious here.

Enrichment materials

Specifically for integrated science curricula there was a need for such materials for both student AND teacher. Such background material should, ideally, be produced locally to meet local conditions, needs and social context. These materials were of particular importance to teachers in situations where the inability to answer students' questions could lead to a serious loss of the students' confidence in the teacher.

Teachers' Guides

Guides that come to grips with the lesson-to-lesson problems faced by teachers were an essential companion to any curriculum project. Such guides should be in an atrractive easy to assimilate form!

e. There was a feeling that teachers' guides should encourage autonomy and a flexible response posture where this was appropriate in terms of teacher professionalism.

Human Resources

The discussion then considered both teachers and students as resources. The organisation of students as collectors of useful material from their environment was mentioned, as was using student interaction with their local community (as outlined in the Yellow Pages) as an important feature of integrated science education.

The activities of groups of teachers (see Fig 1) was discussed. The influence of a group of local teachers who collaborate with one another in the production of resources and the interchange of ideas can vastly improve the quality of education in an area. The activities of such a group needed a supporting curriculum to focus their activities and ensure that they achieve success and satisfaction from their meetings. This curriculum could well be provided by teacher trainers (in conjunction with STAs) and involve the local supervisors/inspectors. Such meetings could find a physical focus for their activities in a local Science Centre.

Such "groups of teachers" work is exciting because it enables rapid implementation of curriculum development in the classroom coupled with rapid feedback to teacher trainers, STAs and inspectors as to their effectiveness.

This concept of "supporting curriculum" can and should be applied to help all "jobs" shown in Fig 1.

The need for trained laboratory technicians was seen as crucial in the maintenance of "scarce resources". A travelling repair service based on a science centre was seen as a means of providing such a service (as the Lagos Unit does in Nigeria).

Science Teachers Associations

These were seen as extremely powerful resources but they often concentrate exclusively on secondary education. This has led to the neglect of science education in the primary sector, where it may be argued that the most important integrated science education takes place. The role of STAs in stimulating interest in primary science was seen as very important and one way in which this might be achieved was by the STA submitting relevant publications to teacher union/organisation-literature aimed at primary teachers.

f. The loss of important resources when a teacher moved from a school was seen as a terrible waste. The role of STAs in recording resources as they are developed as a means of preserving resources was seen here.

The dissemination of information to the "chalk face" was seen as one of the most important roles. The translation of such information into the local language made such information many times more useful. Many teachers felt the need for a validated multiple choice question bank, the provision of this, with ease of teacher access, was something an STA could do.

While this list of resources is not in any sense exhaustive, it does represent those areas of particular concern to those teaching in the developing countries.

## Working Group 7a: Integrated Science Education and Environmental Education

Author: Dr M Dyasi. Chairman: Dr A Blum

Rapporteur: Professor V Wanchoo.

### 1. Place of ISEE

The group considered ISEE as identification of relationships between knowledge, skills and attitudes in integrated science and environmental, social and ethical issues.

## 2. Contribution of ISEE to National Development

a. ISEE must contribute to the development needs of a society - economic, cultural, social, ecological.

b. Education in ISEE must start with the immediate environment, eg problems of health of a child and sanitation around him.

c. The problem in some countries is more economic than ethical. Each nation must put an end to economics of greed and this should be brought to the notice of children and of adults. The role of regional cooperation and the UN and the need for global legislation is significant. Each nation should identify technologies which go along with ethical values and not against them.

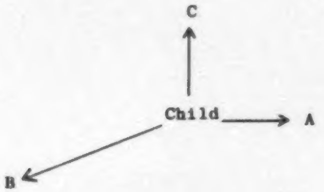
d. Contribution of ISEE should be seen as an expanding spiral - local to regional to global. ISEE should contribute to scientific literacy in such a manner that right political policies are developed in a nation.

e. ISEE should form a part of life-long education through participation in continuing education centres, special centres such as workers' education centres in the UK, and through mass communication media such as TV, radio, and so on. Nonformal activities such as correspondence courses may also be utilised. Community cooperation and support should be emphasised. The place of municipalities and of voluntary agencies in cooperating with ISEE is important.

f. On account of its potential for contribution to national development, it should be accorded high priority in the school curriculum.

## 3. Content of ISEE

a. The consensus of the group was that course content should be selected as shown in the diagram.



A - Environment: physical, biological, social, ethical
B - Processes and methods of science, political decisions and social implications, appropriate technology point of view
C - i. Survey of persistent problems such as waste disposal, conservation, energy;
    ii. Developing awareness of problems;
    iii. Depth studies as the child grows in years.

b. In some countries EE is understood as a perspective and in others as an independent subject for study. The latter is true of some school systems in the USA and the UK. Many Boards of Education in the UK prescribe Environmental Studies as an elective subject for the age group 16-18 years.

In Asia, Africa, and Latin America this subject has yet to find a respectable place in the school curriculum.

c. It is desirable to introduce ISEE in post-compulsory education.

4. Problem-solving, Value clarification, Decision-making and Action

a. The first problem is "problem searching" such as 'why is there no electricity in an area?', 'Why is an area infested with flies, as against another area?'. Some people, having lived in a problem-set for a long time might just take problems for granted, problems just do not exist for them. Identification of problems is, therefore, quite important.

b. When a problem is identified, the "should we" type of question leads to value clarification; "can we" leads to decision-making; "how can we" leads to action. Students therefore should be involved in problem-solving in a manner that helps them to learn decision-making on the basis of collected data. They learn to implement, through action, programmes, and they learn how to make value judgments. The entire breadth of physical, biological, social environment around a child may be tapped to identify problems and their solutions and encourage their implementation for the benefit of society. Control of population is a sensitive problem in some areas. What are the data, what conclusions can be drawn from them, should population be controlled, how? are some important questions which lead to problem solving in EE.

c. Since ISEE is a science, its science must be good, with due emphasis on the processes and skills of science.

5. Organisational Strategies and Teacher Education

a. ISEE must find a place in the teacher education system of a country. Elementary level projects must be fed into the elementary teacher education curriculum; the same should be done with secondary level projects. Teacher educators should see links between their own programmes and ISEE to start with, and gradually develop a fuller perception of problems and experiences in this area of study.

Exposure of teacher educators to ISEE units may be helpful.

Pathways may be developed for this purpose in each country. Resource centres being developed in some countries are examples.

Science teachers' association should assist the growth of this movement.

b. Field Studies Council UK has many centres in the country which offer one-week programmes for students, teachers, parents on EE topics such as marine ecology, freshwater ecology, industrial ecology, etc.

c. LEAs in UK have bought country houses in the interior which are used for students and teachers for recreation, and environmental studies. Museums in UK and India offer courses for teachers and students on EE topics.

d. Science fairs, agriculture fairs, trade fairs organised in many countries are appropriate occasions to expose the school population and lay public to problems issues and experiments in EE. The activity of voluntary organisations such as the National Audobon Society are also useful. Such organisations may be started in all countries.

6. ISEE and examinations

ISEE should be examined in the same manner as other subjects, as a part of a science course in some schools and as an independent subject in other schools. In USA it is examined as a science subject. Adoption of this practice by other countries will help to put the subject on a respectable basis.

7. ISEE and attitudes

a. It is a great challenge to teach ISEE because of its newness and its potential for developing understanding of the unity of science and the unity of the universe.

Being a new area of investigation and study, a teacher should develop an attitude of learning with his students. Since he lacks information, he should be honest with his students in admitting his lack of command over content so that both - the teacher and the taught - can learn together.

A teacher in some cultures is looked upon as an authority but in such cultures also the attitude of learning with students seems to be the trend.

## Working Group 7b: Future development in integrated science in relation to technological studies

Author: Dr A Hofstein. Chairman: Mr N Booth.

Rapporteur: Mr J de Kanter

I: In the first session the working group formulated the starting point:

- Science and technology should be integrated because:

1. the development of each now emphasises their interdependence

2. we have need for people working and living in an increasingly technological society to understand both technology itself and its significance

3. there is ample evidence to show that the introduction of technological elements into science courses can be highly motivating

4. there is a need, in society, for the status of the technologist and technician to be regarded in equal partnership with the academic so that some elements of technology can be introduced to all pupils.

II: In the second session Peter Richmond led the discussion. He gave us his answer to the question: "What are the kinds of problems that students meet in their daily life?"

His starting point was: the average student in an average comprehensive school.

This student is looking for a simple technology and not a complex one. The easiest and perhaps the best way for technological studies to start is by including simple technological problems in a current course.

The weakness of this method is that the equipment and the course must be developed by the teacher

III: After this introduction we spent the day dealing explicitly with the 10 questions that were posed by the author of the lead paper

question 1: What are the changes in secondary science education that are needed for its integration with technology?

- No massive changes are necessary. The inclusion of aspects of technology in existing science courses would suffice. This implies almost certainly that some of the existing course content will have to be omitted, reduced or reorganised to accommodate these new elements.
- A means of focusing on technological problems is to persuade examiners to use related questions in their papers. Teachers will then change their syllabi appropriately.
- The workgroup could not solve the problem: what should have the highest priority, a single course changing to an integrated one or taking up technological problems in it.

question 2: What are the best learning strategies for classroom integration of science and technology in industrial countries and in rural countries?

- The technological problems that are taken up have to be recognizable to the students.

  You cannot just copy the syllabi of others. You must know what kinds of problems are of concern to your students.

  This depends on the local circumstancos (environment) (rural-urban; industrial-agrarian; poor-rich). There is a need for local options. At the same time the introduction of material related to technology should have a broadening effect.
- Another element of strategy has to be that the student, as much as possible, must be interested in the setting up of the problems and experiments.

question 3: What are the best strategies to adopt for teacher training?

- The first goal is to change the atmosphere so that teachers are susceptible to taking up topics of technology in their courses. The working group worded this problem also in another way: "How can we make the less qualified teacher more competent"?
- Possibilities:

  There is a need to provide resources for teachers embarking on this new field

  A source book is needed. It should be filled with all kinds of ideas that can be read and needed by the teachers. We would like UNESCO to consider this.

  Teachers centres are needed.

- An additional difficulty is that the technology is continuously changing and with that the experiences of the students will change. The teacher training programme must pay attention to these changes in technology.

question 4: What changes will the universities need to make in order to accept the students who were taught integrated science?

- The universities have to accept and give their support to the integration of science and technology. The best way of doing this is involving them in the curriculum development.

question 5: What are the areas of integration for schools at the various secondary levels?

question 6: What is the role of industry and technological centres in such developments?

- To have knowledge of all kinds of technological problems there have to be links with local works and trades. Usually industry is willing to give all the information sought. However the materials provided are often public relations oriented rather than education oriented.

  A specific problem exists if the headquarters of an industry are situated abroad (not in developing countries). It is necessary that those who are responsible for the educational affairs within an industry cater for all the countries where the industry has plants, not only in the home country.

  Another role of industrial education centres could be to hand over obsolete instruments and equipment to schools.

question 7: Has educational psychology anything to say against or for such integration?

- There is much to say for such an integration because technological elements within a science course present the possibility of a better match with learning theory and a stronger motivating force for all pupils. Technology is a tool for reaching educational aims especially for those students who are not formal thinkers (Piaget) or those who are too young to do so.

question 8: What are the characteristics of a student who has been through an integrated science course as compared with one who has taken a traditional course?

question 9: Are integrated courses broader or narrower than traditional courses?

question 10: What is the role of mathematics in such courses vis-a-vis its role in traditional courses?

- Mathematics has to help the student in understanding what is happening and how it is happening. It does not have to be a major topic in itself. The student must have the ability to understand what is happening, what has to be done. Mathematics can be useful for understanding the technological matters better.

The outcomes of the discussion were used to answer the question "Does there have to be any difference in topics, in technological problems, in the approach for boys and girls?"

The aims for both are the same:

Girls should not feel themselves helpless with technology and prejudiced against it. It is desirable that both girls and boys should develop sound attitudes as well as competencies with respect to technology. It is largely a matter of understanding the interests of the students and of knowing how they will be concerned with various aspects of technology. Girls do have differences in personality and in expectations.

Therefore there is an opportunity to exploit some of the different aspects of technology. Some groups will have special interests in

1. assembling equipment
2. ensuring optimum usage of equipment
3. care and maintenance of equipment
4. training and diagnosis of faults
5. improvement of design.

There is a spectrum of technological problems and topics varying from the simple to the complex. In developing countries there is no shortage of technological problems even though industrial development is not advanced.

Teachers must be encouraged to use meaningful situations that are close at hand. They should not simply regret the lack of sophisticated examples.

There are problems related to water supply
transportation
communication
health services
agriculture.

There is a need to assist teachers and pupils to develop skills in identifying the scientific principles that are significant with respect to everyday technological problems.

The inclusion of technological aspects in science courses is also crucial for developing countries in improving the attitudes that people have toward the strategically important middle level technology.

## Working Group 7c: Future Developments in Integrated Science Education in relation to Nutrition and Health Education

Author: Professor I Raw. Chairman: Mr D Black

Rapporteur: Mr V Hutchinson

### The Long Term Purposes of teaching Health Education and Nutrition and the Role of Integrated Science

The preventive, supportive and remedial aspects of the long term purposes were identified as follows:

1. Their relevance to the pupil because of their application to his immediate and future well-being.

2. Their large-scale social consequences in:

   a. combating the long-term effects of malnutrition;

   b. prevention of infection and of disease transmitted by parasites.

3. Providing knowledge, skills and processes necessary to secure prevention.

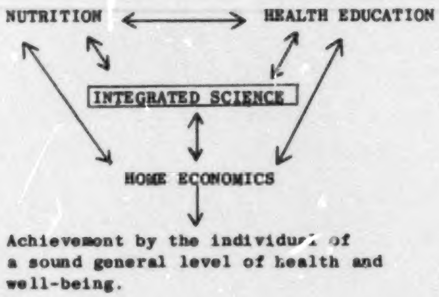
4. Offering approaches to the care of individuals in the family setting and thus creating a transfer of science to solve the practical problems of everyday living. Application could lie partly within the field of home economics.

5. The effect that sound nutrition and health education practices have on physical and intellectual development.

6. Identifying and understanding the 'propaganda' of the mass advertiser and combating misunderstanding and mis-information.

7. Offering makers of social and educational policy a scientific approach to health education and nutrition upon which to base their decisions.

The relationship between the areas of the curriculum involved in the achievement of these purposes can be illustrated as follows:


NUTRITION
HEALTH EDUCATION
INTEGRATED SCIENCE
HOME ECONOMICS
Achievement by the individual of a sound general level of health and well-being.

Problems Identified

There are significant differences in the symptoms and causes of problems when comparing countries that are more developed with those that are less developed. In the former category, chronic conditions are attributed to lack of exercise and inappropriate dietary patterns; young people and adults accept commercial information of questionable accuracy because of the failure to relate information imparted in schools to actual eating patterns and health practices. In the latter group, lack of information often results in the adoption of inappropriate practices eg the replacement of breast feeding by over-diluted milk made from powder and given in unsterilised bottles produces chronic enteritis amongst infants; lack of food both in quantity and variety results in low resistance to infectious and endemic diseases.

## Response Suggested

Relevance, motivation and activity were crucial to success. Learning by re-discovery and by 'doing' with relevant goals based on real-life situations were regarded as essential approaches in the design of science curricula. What appears to have been established is a non-scientific culture based on either mis-information or superstition. The task of the teacher involved in school-based curriculum development is to devise a curriculum which demonstrates the inaccuracy and inappropriateness of popular misconceptions and thus create an opportunity for the transfer of science to real life situations. This would involve:

1. A problem solving approach to learning.
2. The acquisition by the pupil of process and decision-making skills.
3. The application of skills at increasingly complex levels related to developmental stages of growth.
4. A systematic scheme of instruction applicable to education at different levels.

## Levels of Implementation for the Future

Four levels were identified:

Primary School Level: Intellectual readiness is necessary. Children of primary school age are ready to learn through a scientific approach provided it is simple and concrete. In less developed countries, where time for primary education is limited, the pupil must acquire 'a tool' to enable him to transmit his newly acquired knowledge and skills to adults in his family.

Secondary School Level: Requires a spiral curriculum which moves from the concrete to the abstract with increasing levels of complexity but must be related to the developmental age of the pupils. Will integrated science education displace or enrich other areas of the curriculum? The answer depends on the decisions taken within schools at local level as to which aspects could be most effectively taught in which area ie in the laboratory, in the home economics room, or in the area of health education.

Out-of-School Education: Informal continuing education for adults through educational television; mobile film units in rural areas; consumer advice bureaux in urban areas; professional field workers eg doctors, nurses, welfare workers, community dietitians and nutritionists and home economists. The role of the last named lay at the interface between the advances in science and technology...and the individual user of products and services. The task of the home economist was to interpret to the user the possible applications of these advances to enable them to cope more effectively with the problems of everyday living and thus reinforce the healthy scepticism acquired in school towards claims advanced by the media.

Makers of Social and Educational Policy: Influence could be exercised by the scientific community and an informed body of public opinion, though it was thought that the happiness of the individual cannot be expressed exclusively in terms of cost-benefit analysis.

Conclusions: Our concern should be to make science more relevant in response to human need. The emphasis must be on the social context to enable the individual to develop a decision-making process for use throughout life. In a world of finite resources which are rapidly being depleted, greater efficiency in their use is required for survival of the individual and the human race.

## Working Group 8: Relationship of Integrated Science to Other Subjects in the Curriculum

Author: Professor U D'Ambrosio. Chairman: Professor C Quiroz Peralta

Rapporteur: Mr D Harlow.

The working group has begun a somewhat wider examination of the basis of subject integration than the somewhat restricted emphasis on mathematics in the keynote paper.

Special attention was given to integration and coordination of mathematics at the various school levels. The group felt that a broader integration of subjects at primary level was feasible, although perhaps demanding a lot from the present teachers; whereas integration at secondary level faced some additional problems related to the pressures of some inevitable degree of assessment.

Particular attention was given to the interpretation of language which was a major area of concern in the author's paper. "Language" must include communication carried out through formal operations together with that involving gestures, mathematics, music, art forms etc.

The working group is preparing a lengthy report covering various aspects of integrating of the various subject areas, conscious of the fact that science itself uses terms which are not readily accepted by other disciplines. Thus we need to spell out special meanings of common phrases such as "content oriented" by explaining that it could include, for example, skills which can be acquired through a variety of strategies. Development of these heavily depend on the expertise of teachers but must always be related to the experiences of the pupils. This expanded report will develop in respect of a broad group of subjects a coherent picture covering the rationale of integrated school programmes; the importance of content drawn from skills acquired from overlapping subject areas; methodology of achieving integration; the importance of language, culture and societal inputs; teacher expertise which includes initial and in-service course development, especially where separate subject personal education needs re-orientation to successfully encompass the integrative style of education.

A view of the impact of advanced technology on classroom resources will be expressed, again related to the reference to its growing availability in the author's paper. Specific examples of integrated schemes will be referred to and the contribution of the working group will propose some specific actions.

## Working Group 9a: Special problems of dissemination and implementation of integrated science education nationally

Author: Mr B G Pitre. Chairman: Mr J O Ryan

Rapporteur: Dr S H Kellington.

### Introduction

In view of the many problems which have been encountered in the dissemination and implementation of Integrated Science Programmes, it would be highly desirable for such problems to be anticipated at an early stage in the development of a new programme. It should be possible to avoid some of the problems frequently encountered by appropriate planning at the innovatory stage. A logical first step in this planning would be an analysis of problems which have occurred in the national context under investigation. The following list gives some examples:

Problems encountered by innovations

1. Lack of adequate resources (eg time, finance, manpower, laboratories, community resources)

2. Resistance to the innovation by pupils, teachers, parents, school administrators and industrial employers.

3. Constraints imposed by examination systems.

4. Teachers' lack of adequate knowledge of course content.

5. Teachers' lack of the necessary presentation skills.

6. Difficulties of communicating to teachers.

7. Lack of indigenous curriculum expertise.

8. Lack of relevant science background of government administrators.

Of particular relevance to the innovation of integrated science programmes are problems 2,3,6 and 7.

The innovating group

Bearing in mind the problems experienced in completed programmes, it is recommended that the innovating group should consist of a working team supported by personnel and agencies assuming a consultancy role. The working team should include practising science teachers, science educators, and one or more curriculum advisers who would ideally be full-time professionals with a knowledge of the education system of the country and who would assume a coordinating role.

Personnel with other experience may also be included, depending on the country, but the working team should be heavily teacher-centred.

The working party members, as a team, should possess

1. awareness of the social and cultural developments of the country and reflect its current mood

2. knowledge of the science content of the proposed programme

3. knowledge of psychology related to learning

4. knowledge of the national education system and the professional aspects of education.

Consultants to the working team within the innovating group should include those indicated in the schematic diagram in Figure [illegible]. Further recommendations relating to the innovating group are as follows:

1. Practising teachers should be encouraged to assume a key role in the innovating group.

2. The evaluator(s) should be closely associated with the working team from the initiation of the development.

3. Specialist subject experts should be drawn from the areas of science, social science and the humanities.

4. Consultancy should be a two-way process.

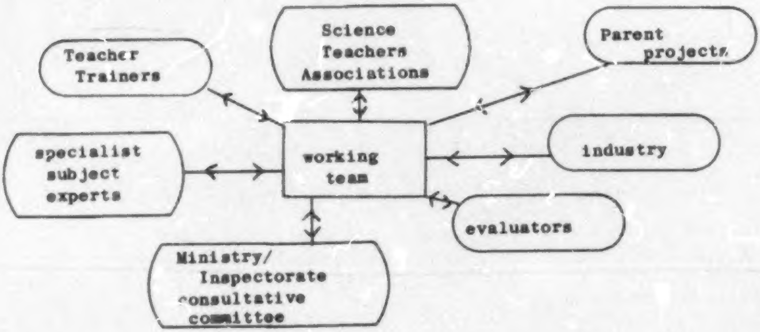
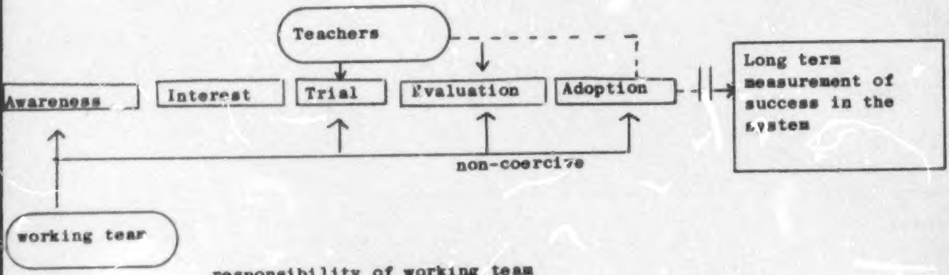

Teacher Trainers
Science Teachers Associations
Parent projects
specialist subject experts
working team
industry
evaluators
Ministry/ Inspectorate consultative committee

Figure 1.

An implication of using the above model is that in addition to ensuring a strong national orientation in the programme, external assistance would be viewed as a contribution to the innovation to be invited by the working team.

Responsibilities (of the working team) in dissemination and implementation

Having established an innovatory group consisting of members with appropriate knowledge, expertise and attitudes, the processes of dissemination and implementation can be further facilitated through exploration, in the national context, of appropriate lines of communication between the innovating group and the teachers who will implement the programme. The flow diagram in Figure 2 illustrates possible lines of communication and emphasizes the responsibilities of the working team. This diagram includes the display of stages in the implementation process which is presented as diagram 1 in the working group paper.


Teachers
Awareness
Interest
Trial
Evaluation
Adoption
Long term measurement of success in the system
non-coercive
working team

responsibility of working team
responsibility of teacher(s)

Figure 2. Stages in the implementation process and responsibilities of the working team and teachers.

The initial responsibility of the working team should be to produce an awareness of the programme in the teaching community. Should interest arise, the working party should initiate and assist with the processes of trial, evaluation and adoption. In particular the working team should:

1. plan the dissemination process

2. ensure that adequate opportunities are provided for teachers not involved in the trials to gain direct experience in using the materials

3. provide for continuous support for teachers after the initial development through, for example, science advisers and in-service programmes

4. plan for the provision of reserves required for the implementation of the programme (eg laboratories, apparatus, materials)

5. plan for a long-term evaluation of the success of the programme.

For dissemination at national level it is recommended that disseminatory teams involving teachers with experience of the programme should be established. Such teams could assume many of the responsibilities of the original innovating group.

## Working Group 9b: Dissemination of Integrated Science Regionally and Internationally

Authors: Professor K Frey, Dr D Lockard, Dr S Selim, Mr J Vaernewijck

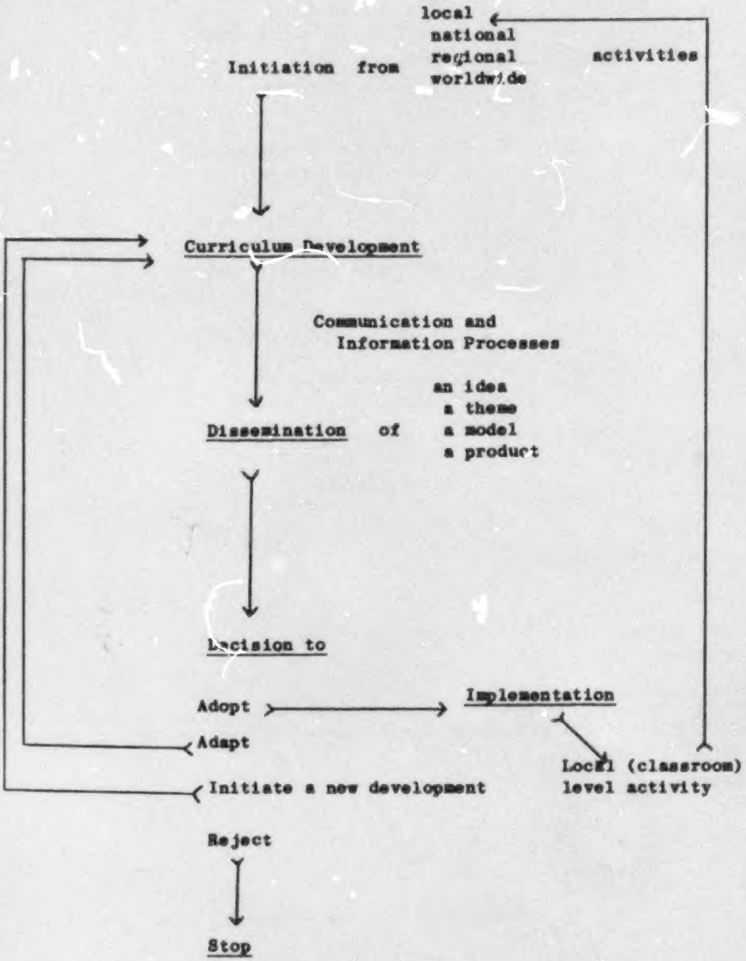
Chairman: Miss F Dalgety. Rapporteur: Dr G Howell

Consideration of the authors' papers gave rise to an attempt to describe diagramatically the curriculum change process.

On this model (overleaf) dissemination is regarded as a complex, often cyclical, process which comes before implementation, which is seen as essentially a classroom level activity.

It was emphasised that teacher involvement was regarded as being essential at all stages.

## Curriculum Change Processes


Initiation from
local
national
regional
worldwide
activities
Curriculum Development
Communication and Information Processes
Dissemination of
an idea
a theme
a model
a product
Decision to
Adopt
Adapt
Initiate a new development
Reject
Implementation
Local (classroom) level activity
Stop

The group then focussed on the process of implementation and identified the following factors which could influence the process.

| | Internal | External |
|---|---|---|
| Aids | Confidence in the subject matter<br>Commitment to the idea and philosophy | Pupil commitment<br>Supportive colleagues<br>Time allocation<br>Rest of the curriculum<br>Support from education authorities<br>" " " organisations<br>" " parents<br>Acceptance by higher education<br>Job opportunities<br>Adequate teacher education and training<br>Adequate logistic support<br>Rewards (appreciation)<br>Examinations |
| Hindrances | Lack of confidence in the subject matter | Drop in status |

It should be obvious that many of the converse expressions of Aids would in fact be Hindrances.

Two items were briefly analysed further.

**Rewards**
- Affective
- Intellectual
- Professional
- Promotion
- Financial
- Access to further education and training
- Pupil success
  - Involvement in research and Curriculum Development

(Not all of these may be operative in all cases)

**Logistics**

- Printed matter
- Laboratory facilities
- Laboratory equipment
- Audio-visual materials
- Technical assistance, etc
- (Refer to report of Working Group W6)

Considerable emphasis was placed on the development of new and more adequate patterns of teacher education. Whether this contained a strong element of single disciplinary training or not, it was thought essential that some form of "science" course, where the major concepts and themes of science could be studied, was an essential component of such preparation. This field should offer considerable scope for international cooperation. (Refer to the report for Working Group W3).

It is possible to work back from this pattern of factors affecting Implementation to a parallel analysis of the Dissemination activities.

**Dissemination**

| Factor | Level of effect | Characteristic |
|---|---|---|
| **Aids** | | |
| Person to person contact | Ideas | Mechanisms |
| Information systems | Themes | |
| Accessible resource collections | | |
| International newsletters | | |
| Publishers propaganda | | |
| Provision of financial physical and human resources | Models<br>Products | |
| Supply objective analysis of problems and evaluation of products | | |
| Accessibility to decision-making authorities | Ideas<br>Themes | Foci |
| Strong level professional associations of science teachers | Models<br>Products? | |
| Wish to participate in international development of philosophy and strategy for science education development | Ideas<br>Themes | Attitudes |
| Understanding of degree of advance in the curriculum model or materials | Models<br>Products | |
| Adaptability to match local characteristics | | |
| Receptivity to innovation and attitudes to change (for whatever purpose) | Ideas<br>Themes | |
| Prestige value of association with international bodies | ? | |
| **Neutral** | | |
| Degree of centralisation of the education system | | Mechanisms<br>Foci<br>Attitudes |

| Factor | Level of effect | Characteristic |
|---|---|---|
| Hindrances | | |
| Differences in educational systems | | Mechanisms |
| Structures and assessment patterns | | |
| Level of teacher competence and performance | Models<br>Products | |
| Level of sophistication of curriculum model and materials | | |
| Language barriers (variable) | | |
| Non-availability of required materials | | |
| Vested interests in preserving status quo | Models<br>Products | Attitudes |
| Existing value systems and prejudices | Ideas | |
| (There must be a dissatisfaction with what exists as a motivation for innovation and change.) | Themes | |

This analysis has attempted to identify both the level of dissemination which is principally affected by the factors quoted and to indicate the characteristics of the factors. It is then easier to decide what areas may be amenable to international or regional cooperation in a given set of circumstances. Some explanatory comment is required.

### Information systems

While the group agreed that improved information systems were required, it did not agree that new information systems were necessarily required for integrated science. A strong opinion was expressed that it would be better to concentrate efforts on improving existing systems and making them more responsive.

### International agencies

In recognizing the valuable role which such agencies could play in the dissemination activities, it was stressed that they should be careful to respond to clearly felt local needs, and that the agencies should be more ready to develop a sensitivity to local attitudes. The "selling" of ideas, themes, models and particularly products was strongly opposed.

### Cooperation

While some limitations were recognised, there are strong mechanistic reasons for regional and international cooperation. Such activity can avoid a considerable amount of duplication of effort and replication of mistakes. There are also benefits to be gained from the sharing of insights and experience. Against this has to be set the factor that no curriculum is likely to be transferable in its entirety from one country to another, and cooperation is more likely to be successful at the model and local adaptation level rather than at purely "product" levels. Regional cooperation might be also particularly valuable in the developmentof programmes for teacher education. It was recognised, however, that the "regionality" or the desire for "association" would have to pre-exist for factors other than just those of the desirability of developing cooperatively new school curricula. Regional activity does not provide a complete substitute for local activity, rather it makes the latter more efficient.

## The classroom situation

In all the discussions the need for visible impact at classroom level was stressed. It is difficult for external agencies or organisations to operate down to classroom level. However, as few obstacles, or intermediate stages, as possible should be put between the teacher and the information and resources he requires.

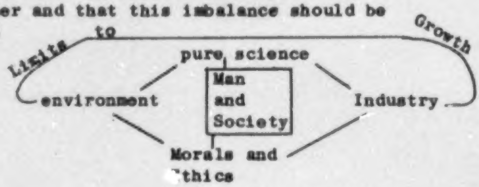
## Working Group 10: Science, Society and Trends in Science Education

Authors: Mr J Lewis, Mr R Silber.

Chairman: K Bruggemans; Sub group chairman: J M Gutierrez-Vasquez

Rapporteurs: I W Williams, R Hill.

Mr John Lewis presented his working paper and the initial discussion centred on the concentric model: Science for the Enquiring Mind/Science for Action/Science for Citizens. There was general agreement that science teachers have overconcentrated on the former and that this imbalance should be corrected. The author formulated a further model to show the relationship of man and society which could be the main themes of Science for Citizens.



## Aims

a. To understand the nature and limitations of scientific knowledge.

b. To appreciate that the use of scientific knowledge can be both beneficial and detrimental to society and environment.

c. To appreciate that the Earth's resources are finite.

d. To understand the need for, and to develop, the ability to make reasoned decisions which take account of all relevant constraints. To recognise that moral considerations are involved in decision-making.

e. To obtain a realistic picture of the scientist working in society and especially the kinds of constraints which affect his contribution to society.

The public, possibly through the influence of the media, has either a blind faith in the power of science to solve all the problems of society, or sees science as the source of major social problems. We feel that it is important to correct both these impressions.

The limitations of science, both intrinsic (eg thermodynamic) and philosophical (the inadequacy of science on its own to solve problems of society) must be emphasised, but not at the expense of the power of science and the contribution which it has made to raising man's expectations and improving the quality of life.

Science teachers should adopt a positive approach to the critical issues that constantly surround us.

Some Topics for Study (a) Energy (b) Population (c) Natural and Human Resources (d) Food and Agriculture (e) Social Medicine (f) Engineering and Industry (g) Communications and Data Handling.

Some reference to the following: (j) the use of mathematics (k) the history of science (l) the nature of science and religious belief (m) science and government (n) poverty (p) human relationships.

All these topics are felt to be relevant to both developing and developed countries but the selection of topics and the emphasis placed will vary from country to country. The subject is felt to be relevant to pupils of all ages. The focus for younger pupils will be on local issues, but older students will be able to consider world wide issues.

Some existing science programmes dealing with social implications were identified.

For example:

1. Australian Science Education Project (ASEP) 11-16 year-old pupils Curriculum Development Centre, PO Box 632, Manuka, ACT 2603, Australia
2. Higher School Certificate-Physical Science (17-18 year-old pupils) Monash University, Wellington Road, Clayton 3168, Melbourne, Australia
3. ASE Science in Society Project (16-17 year-old pupils) (UK)
4. Learning Science - An Integrated Science Curriculum (11-13 years) for Indian Schools (NCERT, India)
5. Science and Society (16-18 years), an integration of science, language and society for Indian Schools (NCERT India).

In principle the group felt that consideration of social issues should be incorporated into regular science programmes, whilst recognising the dangers in a pure science approach to social issues where the perspectives of the philosopher, historian, economist etc are equally necessary. In any case the science teacher will have a major contribution to make, and may have to take the initiative. For older pupils at least it may initially be necessary to offer Science and Society courses to complement regular science courses. We recognise that know-how on teaching methods is still extremely limited and that teachers will need a great deal of up to date supporting material.

The group discussed a second working paper by Dr R Silber presenting a personal viewpoint on the education required to enable the next generation to cope with technological change, but in the absence of author it proved impossible to question the assumptions upon which thepaper was based. Seven other papers by members were discussed and the group would wish to see N Sabar's survey of curriculum trends involving Social Issues in Science Education published, since it complements John Lewis's paper with many examples. We trust that the outstanding plenary lecture of the Dutch scientist-politician Dr J C Terlouw will be published in full.

The main principles outlined appear to have been acceptable to the great majority of the group. The absence of members from many areas of the world, and the different educational philosophies that they represent suggest however that we should refrain from generalising claims for the approach proposed.

# CHAPTER 4: Papers Submitted to Working Groups, Poster Sessions and Exhibitions

## A. WORKING GROUPS

### Working Group 1: Aims and Objectives of Integrated Science Education

D G Marshall: An account of a new ILEA science teaching project for 11-13 year-old students

J K Sood: Extracts from 'Integrated science for the middle stage of 10-12 curriculum in India

M S Al Rashidi: Man as the centre: the anthropic approach

H H ten Voorde: A note on the WEI project in selected Netherlands secondary schools.

### Working Group 2: Design and content of integrated science courses

| | |
|---|---|
| Akin O Osiyale | The Nigerian Integrated Science Project Example |
| Mohammad Abu Sal | Status of Integrated Science in Jordan |
| Niels Bandholm | Educational System of Denmark |
| Olusola A Oyetola | The Status of Integrated Science in Nigeria |
| Winston K King | The Status of Integrated Science in the Caribbean |
| R M Garrett | Integrated Science in the United Kingdom |
| Evhan Uzwyshyn | An Integrated Design of the Junior High Science Program in Manitoba |
| David C Cox | The Development of Content and Structure for Integrated/Unified Science Courses |
| Carl Jorgen Veje | Teaching of Integrated Science in Denmark |
| J R Winter | Integrated Science Education in Tasmania |
| Nicole de Haese | The Situation of Integrated Science in Flemish State Schools (Belgium) |
| Jitka Fenelova and Ludek Pekarek | Structure of Matter as Integrating Factor in Science Education |
| D A Black | The Status of Integrated Science Education in British Columbia, Canada |
| Charles J Xerri | Integrated Science - the Maltese Project |
| A P Hendriks | Scheme of the Educational System in Holland |
| C de Kock | Integrated Science in Holland |
| Paul Vegting | Status of Dutch Integrated Science: Stages in a curriculum |
| H H ten Voorde | Why and How |
| Norman Massey | Across Disciplines |
| Both, Kees, et al | Integrated Science Education in the Netherlands |
| O P Puri | Cooperative General Science Project |
| S T P Bundu | Core Course Integrated Science in Sierra Leone. |

## Working Group 3: Education of teachers for integrated science

| | |
|---|---|
| M Arca and M Vincenti-Missoni | Integrated Science: Meaning and Aims for Teachers, for Children,with Respect to Disciplines, with Respect to Society |
| J L Lemke | Helping Teachers Widen Social Access to Science |
| T C Mani | Education of Teachers of Integrated Science at Ahmadu Bello University in Nigeria |
| C A Quiroz Peralta | National Programme for the Improvement of Science Education in Peru - a Case Study |
| G Verkerk | Radioactivity and Training of Integrated Science Teachers |
| L A Casciato | Avoiding the curricular crutch. |

## Working Group 4: Strategies and Implementation of Integrated Science Education

| | |
|---|---|
| Rufus Alabi | Strategies and Implementation of Integrated Science Education at the Secondary Level |
| Peter Pezaro | Semi-integrated science: an experiment in geochemistry |
| David Slimming | Some Factors Influencing the Implementation of Secondary School Integrated Science in the Third World, with Special Reference to the Swaziland Integrated Science Project |
| H F Varela, S J Del Rio and A J Furlan | Ensenanza de Ciencia Integrada para la Formacion del Medico Experiencia de un Cambio Curricular en la Enep-Iztacala-Unam |
| M L Amarasekera | Strategies and implementation of integrated science at the secondary level. |

## Working Group 5: Evaluation of Integrated Science Education

| | |
|---|---|
| David A Churchman | Natural Experimentation as a Means of Conducting Evaluation |
| S H Kellington | Production and Evaluation of the New Materials for Scottish Integrated Science |
| S A Lutterodt | The Interaction of Theoretical and Contextual Considerations in Planning the Evaluation of an Integrated Science Course in Ghana |

### Working Group 6: Resources for integrated science education

| | |
|---|---|
| L Bojorquez, S C Galvan and E Molina | Production of a didactic system for teaching-learning situations in integrated science courses |
| S Allegokoen | Preparation and testing of integrated science education in primary schools. |

### Working Group 7: Integrated science and environmental education, nutrition health and technological education

| | |
|---|---|
| M S Geller | The relationship between integrated science and environmental education: a teacher's view |
| A Blum | Agriculture as environmental science project |
| L F Capurro | Integrated science education and environmental education |
| K Hecht | The case for and against academic science and technology in school |

### Working Group 8: Relationship of integrated science to other subjects in the curriculum

| | |
|---|---|
| A D Turner | A plea for cooperation between mathematics and science teachers in secondary schools |
| R W de M Maclay | Integration of primary school experiences |
| N Massey | Links with other school subjects |
| W E Braithwaite | Relationship of integrated science to other school subjects in the curriculum. |

### Working Group 9: Special problems of dissemination and implementation of integrated science education nationally and internationally

| | |
|---|---|
| S Allegokoen | The extension of field centres to Sri Lanka |

### Working Group 10: Science and Society

| | |
|---|---|
| M Arca | Integrated science - meaning and aims |
| B Ganguly | Science and Society - a few points to ponder |
| P Manzelli | A general outlook on science and society |
| Al Rashid | Man as the focus in science and society - an anthropic approach |
| N Sabar | Social issues in science education - a review |

| | |
|---|---|
| J K Sood | A search for relevance in the developing countries |
| H ten Voorde | Changes in cultural-social frames of reference. |
| J H Raat | Physics in the Society. |

B. POSTER SESSIONS

| | |
|---|---|
| Scotland | General Teachers' Guide to revised Scottish Integrated Science (Editor: John Hughes) |
| M Krasilchik | An effort to renew science education; Sao Paulo Science Teaching Center (1965-1977) |
| B Ganguly | Integrated Science in the school education of India |
| T C Mani | An experiment in integrated science teacher education; the Ahmadu Bello University model |
| C A Quiroz | National programme for improvement of science education in Peru (Pronamec) |
| Van der Rijst and K Klosse | Teaching Science: a course for teachers |
| C J Xerri | Integrated science; the Malta project |
| F Kitselaar | Model of teaching science in Holland |
| Nigeria | Nigerian Integrated Science Project - S.T.A.N. |
| J Stevenson, P Fensham, I Winter and J Atkinson | Australia Science Education Project (ASEP) |
| J H Raat | Physics in society |
| J Hannsens and M Verbeke | Interdisciplinary laboratory courses; organisation and evaluation of student performances |
| T L Liem | Discrepant events for the enhancement of the learning process in science |
| S A Lutterodt | Translation of curriculum intention to classroom as mediated by the teacher. An analysis of resources required for the implementation of Ghana's project for science integration |
| H J Arzi, N Orpaz and Y Sivan | From elements to compounds; an integrated physical science course (Israel) |

| | |
|---|---|
| A Blum | A curriculum adaptation scheme (Israel) |
| D Slimming | The introduction of integrated science in Swaziland |
| J Fenclova | Structure of matter as integrating factor in science education |
| T Gadsden and P Becht | FUSE Center at Florida: display of integrated science programmes from 20 countries |
| ICSU CTS | Contribution of various science disciplines to the teaching of science at school level (Editor: M Matyas) |
| F D Goar | A decade of T.H.I.S. (Toward Humanisation and Individualisation of Science) |
| I Winter and J Stevenson | Integrated science projects operating in Australia |
| R Zuzowsky | 'MATAL' project, Tel Aviv University; Intensive evaluation |
| C D O Jenkins | International Baccalaureate - integrated science courses |
| J Bowles | Field centres for teachers in Sri Lanka |
| H van Aalst | PLON-materials: project curriculum development in physics |
| D Marshall | Insight to Science - integrated science project for 11-13 year-olds (UK) |
| V Hutchinson | Focus on home and family; Schools Council project Home Economics in Middle Years |
| J L Hornsby | A review of integrated science in the 11 16 age group in the UK (ASE) |
| P J Teernstra | The use of school environment in elementary integrated science |
| T A Balogun | Strategies of educational change and the implementation of inegrated science with special reference to Nigeria |
| UNESCO | Display of UNESCO publications related to integrated science |
| V Hewitt | Jamaica integrated science (video presentation) |
| P Pilgrim | Discovery learning; an outline (video) |
| B Shaul | The blood (video) |

## C. EXHIBITIONS

The following individuals and organisations arranged exhibitions:

- P R Richmond, University of Southampton, UK
- Addison-Wesley publishers
- BP Educational Service
- Griffin and George Limited
- Heinemann Educational Books
- John Murray publishers
- Leybold-Heraeus BV
- Philip Harris Limited
- Philips Nederland BV
- Wolters-Noordhoff BV
- British Council book exhibitions.

# CHAPTER 5: Evaluation of The Conference

Two evaluation teams were established for the conference - one mainly concerned with administrative matters (convenor: Mike Chadwick), the other with professional aspects (convenor: Norman Massey).

The following are extracts from their reports:

## 1. Personal information

| | | |
|---|---|---|
| Experience as classroom teacher only | 9%) | ) 73% |
| Experience in more than one field INCLUDING classroom teaching | 64%) | |
| Experience in teacher training and/or curriculum development (WITHOUT classroom experience) | 20% | |
| Experience as university teacher only | 6% | |
| Experience as educational administrator only | 1% | |
| No previous experience with integrated science | 17% | |
| A little previous experience only | 35% | |
| More than a little previous experience | 46% | |

## 2. Pre-conference information

Participants were asked for a rating regarding advance information about professional aspects of the conference. 56% of those replying were more or less dissatisfied and the mean rating was the lowest recorded on the questionnaire.

Many of those commenting (33) complained that information arrived too late, particularly from certain authors, and almost half of these added that there was, in any case, not enough information on the professional side (people would like to have been referred to the 'New Trends' publications for example and a more detailed discussion of the aims and level of the conference would obviously have been welcome).

A lot of those replying would have liked more advance information regarding what was intended at the poster sessions and a few would also have liked to know about the roles of authors and others (and of contributed papers) in advance.

## 3. Plenary sessions

The most frequent comment was that more time should be allowed for questions and discussion and it was suggested that abstracts of the papers could have been presented in advance to facilitate this. There were a number of suggestions that more speakers from outside the world of the professional science educationist would have been desirable and that more controversial papers would have enlivened things. A number of people felt that the needs of the Third World and of centralised systems of education were not adequately reflected. A few felt that the approach was often too theoretical/academic and that the classroom situation was not adequately reflected. Finally a few suggestions were received that the plenary sessions should have been more closely related to the working group tasks.

## 4. Working groups

Separate responses were requested for weeks one and two. Participants were asked which groups they worked in, how many people there were in the group or sub-group in question and whether this was too many, too few or about right. The answers to the last two questions seem to indicate that, although a number of participants felt that groups of over 10 were too large, a majority were happy with groups of up to about 30.

Comments (57 received, 44 reported)

Others objected to being assigned to groups in advance and it was suggested that working groups should start later on in the programme, being set-up on the spot to meet needs identified at the conference. Quite a number of people felt that the author's papers restricted discussion unduly and a number also felt discussions tended to be too theoretical. These comments were often linked to requests for case studies and for more time for the poster sessions. A number of people again felt that the problems of the Third World and of centralised educational systems were not adequately represented; there were some suggestions that separate groups should be formed to cater for these problems. There was quite a lot of comment regarding what was felt to be poor chairmanship and, particularly, poor reporting - language problems were often mentioned in the same connection. A frequent comment was that the chairman and rapporteurs must work very closely together and that at least one of them should be a native speaker of English.

There were a couple of comments (presumably from authors?!) that the authors did not have enough time to prepare their final trends papers.

## 5. Posters sessions

Many participants asked for more advance information about the poster sessions and a number for more time to be devoted to this activity. A number of people stressed that they found the poster sessions particularly useful (reflecting the equal highest mean rating recorded on the questionnaire). A couple of participants noted the importance of ensuring that posters are manned at all times during the poster sessions.

## 6. Educational visits

All of those commenting found the visits useful or interesting but most added that they made relatively little contribution to the professional aspects of the conference.

## 7. "Integrated Daily"

The Integrated Daily came in for much praise and a number of people felt that it made a marvellous contribution, especially considering the time constraint.

## 8. General

A number of comments related to the value of informal contacts made during the conference. Some of the points made separately regarding the plenary sessions and/or working groups were repeated by a few who felt the conference sometimes operated on too theoretical a level, and that the Third World needed more attention. The formation of mutual interest groups, eg Third World, primary/secondary/tertiary, regional groupings etc early in the next conference was suggested, as was the idea of getting the classroom teachers more actively involved. There were finally a suggestion that the conference needed to be 'restructured' towards the end in such a way as to avoid any loss of impetus.

# CHAPTER 6: Summary of Programme

The programme for the conference was as follows:

| | | |
|---|---|---|
| 28 March | ICASE General Assembly:Registration | |
| 29 March | Opening ceremony | P1 |
| | Interaction of Science and Society by Dr J C Terlouw | P2 |
| | Working Groups | W1 - W6 |
| 30 March | Review of integrated science courses worldwide by Sheila Haggis and Philip Adey | P3 |
| | Working Groups | W1 - W6 |
| | Reception by Lord Mayor Nijmegen | |
| 31 March | The Case for Teaching Science as a Unity by Dr V Showalter | P4 |
| | Working Groups | W1 - W6 |
| | Reception and dinner by NVON | |
| 1 April | The implementation of integrated science by Professor J F Rutherford | P5 |
| | Optional visits to Kroller Muller Museum and Rijksmuseum Amsterdam | |
| 2 April | Optional visit to Flevohof | |
| | ICASE General Assembly | |
| 3 April | The environment as an integrating factor in science education by Professor Rais Ahmed | P6 |
| | Poster session | |
| | Working Groups | W7 - W10 |
| 4 April | Educational visits to schools in Nijmegen, Ede, Velp, Waalwijk, and Wijchen | |
| | Poster session | |
| | Working Groups | W7 - W10 |
| | Reception by British Council | |
| 5 April | Educational visits (continued) | |
| | Visit to Philips Evoluon Eindhoven | |
| 6 April | Educational visits (continued) | |
| | Working Groups | W7 - W10 |
| | Conference dinner | |
| 7 April | Where have we got to, where are we going | P7 |
| | Closing ceremony | P8 |

# CHAPTER 7: List of Participants

Aalst, Drs. H.V.v.
PLON, Princetonplein 1
Utrecht, Netherlands.

Abu Sali, M.A.K.
P.O. Box 1930,
Amman, Jordan.

Alexander, D.S.
Dominica Grammar School,
Roseau, Dominica, West Indies.

Adey, P.S.
90 Lillie Road,
London SW6, U.K.

Ahmed, Dr. Rais
University of Kashmir,
Srinagar, Kashmir, India.

Al-Ani, Dr. R.A.
College of Education,
Baghdad, Iraq.

Al-Massoom, Jasim,
Ministry of Education,
Mansoor 35/1/31, Baghdad, Iraq.

Al Rashidi, Dr. A.S.
Ministry of Education, Bahrein.

Al-Masyed, Dr. M.I.
College of Education,
P.O. Box 157, Abha, Saudi Arabia.

Alebi, Dr. S.R.
University of Ilorin,
PMB 1515 Ilorin, Nigeria.

Alejo, Miss L.
Biologisk Institut,
Danmarks, Laererhojskole,
Emdrupvej 101, 2400 Copenhagen NV.
Denmark.

Ali, Ibrahim M.
Ministry of Education,
Kuala Lumpur, Malaysia.

Allega[illegible]en, Mrs S.R.
Muslim Ladies College
Colombo 4, Srilanka.

Amarasekera, M.L.
154 Badulla Road,
Nuwara Eliya, Srilanka.

D'Ambrosio, Prof. U.
IMECC,
Unversidade Estadual de Campinas
13100 Campinas, S.P. Brazil.

Antwerpen, Ir, A.P.
Achterweg 43,
Heukelum, Netherlands.

Arca, Prof. M.
Centro Acidi Nucleici,
Istituto Fisiologia Generale,
Universita di Roma
Roma 00100, Italy.

Arnold, Drs. F.C.J. M.
Woezikseestraat 473
Wijchen, Netherlands.

Arzi, Ms H.J.
Science Teaching Dept,
Weizmann Institute of Science,
Rehovot, Israel.

Ashiba, N.
5-22 Shimomeguro 6-chome Meguro-ku,
TOKYO 153, Japan

Atkinson, J.M.
Rusden State College
Blackburn Road, Clayton Vic 3168
Australia.

Atua-Baadu, E.
Ghana Education Service
P.O. Box M45.
Accra, Ghana.

Atwood, B.G.
A.S.E. College Lane,
Hatfield, Herts, U.K.

Bajah, Dr. S.T.
Institute of Education,
University of Ibadan,
Ibadan, Nigeria.

Bandholm, N.M.
Bakkegaarvsvej 26,
DK-8240 Risskov, Denmark.

Bar, Ms V.
Hillel 4,
Jerusalem, Israel.

Barlex, D.
23 Thompson Street,
New Bradwell,
Milton Keynes, Bucks. U.K.

Barneveld, G.v.
Tiberdreef 4,
Utrecht, Netherlands.

Becht, Dr. P.
University of Florida,
Box 12639
Gainesville, Florida, 32604, USA.

Beetlestone Prof. J.
Department of Education,
University College, Cardiff, U.K.

Ben Shaul, Ms R.
Isaac Sade Street 5,
Neve Magen, Ramat Hasharon, Israel.

Black, D.A.
1640 Berkeley Road
North Vancouver, Canada.

Blänsdorf, Dr. K.
Institute for Science Education.
Olshausenstrasse 40-60
D-2300 Kiel 1, Germany (FDR)

Bleijerveld, K.
Smalmaatstraat 17,
Losser, Netherlands.

Blum, Dr. A.
P.O. Box 12,
Rehovot, Israel.

Bojorquez, Prof. L.
Teja 158,
Jardines del Sur,
Mexico, 23, DF Mexico.

Booth, N.
104 Moss Lane,
Sale, Cheshire, U.K.

Both, K.
Telgenkamp 19,
Oldenzaal, Netherlands.

Bowles, J.
c/o British Council,
Colombo, Srilanka.

Brenden, Dr. R.v.d.
1420-45th Street,
Desmoines, Iowa 50311 U.S.A.

Brathwaite, W.
U.W.I. School of Education
Cave Hill,
Barbados, West Indies.

Brockmeyer, H.
Lönstrasse 9c
D-347 HOEXTER, Germany (FDR)

Broekman, Drs P.
Burg. L.v.
Aduardstraat 22,
Zetten, Netherlands.

Bruggemans, K.
BRT Schooluitzendingen
Reyerslaan 52,
1040 Brussel, Belgium

Bruijn, Ir, I.de
Albert Sommerstraat 15
Hengelo, Netherlands.

Bulthuis, Mrs. G.
Theemsdreef 436, Utrecht,
Netherlands.

Bundu, S.T.P.
Ministry of Education,
Freetown, Sierra Leone

Burdy, B.
St John's High School,
401 Church Ave,
Winnipeg, Manitoba, Canada R2W1C4.

Capaccio, E.
Via Veneto 91
25042 BORNO (BS) Italy

Caparro, Prof. L.F.
Esteban Dell'Orto 6875,
Las Condes,
Santiago,Chile.

Casciato, Prof. L.A.
724 W. Cobbs Crk Pkwy,
Yeadon, Pennsylvania 19050, U.S.A.

Chadwick, B.T.
The British Council
10 Spring Gardens, London SW1, UK.

Cheong, Prof. S.Y.
Faculty of Education
University of Malaya,
Kuala Lumpur, Malaysia.

Chisman, D.G.
British Council,
10 Spring Gardens, London SW1, U.K.

Chung, C.M.
Argyle Street,
Kowloon, Hong Kong.

Churchman, Dr. D.
National Science Foundation,
Washington DC 20550, U.S.A.

Cingel, Drs. N.A.
Fazantweg 22
Paterswolde (Gr.), Netherlands.

Cordell, A.J.
John Murray Publishers,
50 Albermarle Street,
London W1, U.K.

Cox, D.
13504 S.E. Oatfield Road,
Milwaukie, Oregon 97222, U.S.A.

Dalen, Dr. M.J. v.
Molenstraat 43,
Ophemert, Netherlands.

Dalgety, Mrs F.
Ministry of Education
P.O. Box 1014,
Georgetown, Guyana, South America.

Davison, T.
Addison Wesley Ltd
4 Hills Place, London W1, U.K.

Dawson, Prof. G.
Florida State University,
Tallahassee, Florida, 32306

Dekkers, Drs. F. Th.H.
Mollerinstituut,
Sportweg 10, Tilburg, Netherlands

Dood, Dr. W. de,
Sint Sebastiaanskapelstraat 38,
Weert, Netherlands.

Douglass, R.
65A Belmont Circular Road,
Belmont, Port of Spain,
Trinidad, WI

Dyasi, Dr. H.M.
SEPA Secretariat,
P.O. Box 9169 Airport,
Accra, Ghana.

Davids, Drs. W.
DeRookamer 27,
Heiloo, Netherlands.

Ellermeijer, Drs. A.L.
Nat.Lab V.U. de Boelelaan 1081,
Amsterdam, Netherlands.

Elwell, M.J.
Philip Harris Ltd,
Lynn Lane, Shenstone, Staffs U.K.

Erlwanger, Dr. S.H.
University of Botswana & Swaziland,
Private Bag 0022
Garborone, Botswana.

Faulkner, H.
Marske Millhouse
London Road, Sunninghill, Berks U.K.

Fensham, Prof. P.
Monash University,
Clayton, Victoria, Australia.

Fernandez, Dr. H.
Apartado Postal 129-A,
Satelite, Estado de Mexico,
Mexico City, Mexico.

Ferreyra, Dr. R.
Magdalena 160,
Santiago, Chile.

Fijnaut, J.J.F.
Nassaustraat 7,
Bunnik, Netherlands.

Fowler, M.A.
Ministry of Education,
Freetown, Sierra Leone

Fox, Dr. R.
5562 Dalhousie,
Prince George, British Columbia,
Canada.

Frey, Prof. K.
Institute for Science Education
Olshausenstrasse 40-60,
Kiel D 2300 Germany.

Furlan, A.J.
Apartado Postal 129-A,
Satelite,
Estado de Mexico, Mexico City,
Mexico.

Gadsen, Dr. T.
P.K. Yonge Laboratory School,
1080 SW 11th Street,
Gainesville, Florida 32611 USA.

Galvan, Ms S.C.
Instituto de Investigaciones,
Biomedicas UNAM
Ciudad Universitaria, Mexico 23 D.F.
Mexico.

Ganguly, Prof. B.
N.C.E.R.T.
Sri Aurobindo Marg
New Delhi 110016 India.

Garrett, R.M.
46 Grasmere Road,
Luton, Beds, U.K.

Geller, H.
Box 413
Lee, Mass 01238 U.S.A.

Geller, Prof. Molly S.
5787C Sims Road,
Delray Beach, Florida, U.S.A.

Gil-Munoz, Rev. V.
61 Victoria Road,
London W8, England.

Goar, Dr. F.D.
517-45th Avenue,
East Moline, Ill. 61244, U.S.A.

Godfresden Dr. E.A.
12 Walnut Street,
Brookline, Mass. 02146 U.S.A.

Grier, T.
1119 15th Street N.W.
Calgary Alberta, Canada, T2N 2B5.

Gunneweg, Ir, J.J.
Wilgendal 37,
Maassluis, Netherlands.

Gutierrez-Vazquez, Prof. J.M.
Jose Ma. Velasco 101
Mexico 19, D.F. Mexico.

Haarlem, Drs. R.v.
University of Nijmegen
Nijmegen, Netherlands.

Haese-Banckaert, Ms.N.M.J.C.
8510 P. Breughelstraat 12
8510 Kortrijk-Marke, Belgium

Haggis, Mrs. S.M.
Division of Science,
Technical and Vocational
Education UNESCO
Place de Fontenoy,
75007, Paris, France.

Hall, W.

Hanssens, I.
KUL Campus Kortrijk,
Afd, Wetenschappen,
B-18500 Kortrijk, Belgium.

Harlen, Mrs. W.
Shalom, East Garston,
Newbury, Berkshire U.K.

Harlow, D.W.
The Royal Society,
6 Carlton House Terrace,
London SW1, UK.

Heimeriks, P.W.M.
Vikkerhoekweg 35a,
Hengelo, Netherlands.

Hendriks, A.P.
Ontginningsweg 85
Usselo, Netherlands.

Herzog-Haesendonck, Y.
Elewytsesteenweg 190
1840 Eppegem, Belgium

Hewett, Mrs. V.A.
University of the West Indies,
Mona, Kingston 7,West Indies.

Hill, Dr. R.R.
The Open University,
Walton Hall, Milton Keynes, U.K.

Hoekman, Ir. J.
Lange Voorst 209,
Oegstgeest, Netherlands.

Hofs, Dr.E.
Oude Woudenbergse Zandweg 1,
Zeist, Netherlands.

Hofstein, Dr. A.
The Weizmann Institute of Science,
Rehovot, Israel.

Holford, D.
21 University Road,
Leicester LE1 7RF, U.K.

Holman, Drs. A.
Frisialaan 23,
Harderwijk, Netherlands.

Hondebrink, Drs. J.
dr. Zamenhoflaan 216,
7522 AW Enschede, Netherlands.

Hoogeveen, J.
Von Weberlaan 1,
Enschede, Netherlands.

Hopkinson, Ms S.
British Council,
10 Spring Gardens, London SW1, U.K.

Hornsby, J.
66 Broadway,
Blyth, Northumberland, U.K.

Howell, Dr. G.
Ministry of Overseas Development,
Eland House, Stag Place,
London SW1, U.K.

Hughes, J.A.R.
6 Claypotts Terrace,
Broughty Ferry, Dundee, U.K.

Hutchinson, V.G.
F.L. Calder College of Education,
Dowsefield Lane, Liverpool, U.K.

Huys, R.
Kloosterstraat 59,
9220 Merelbeke, Belgium.

Janner, Prof. A.
University Nijmegen,
Nijmegen, Netherlands.

Jara del Rio, Dr. S.
Apartado Postal 129-A
Satelite Estado de Mexico,
Mexico City, Mexico.

Jaspers, Drs. H.
Jacob van Lennepstraat 315,
II Amsterdam, Netherlands.

Jenkins, C.
Atlantic College,
St Donats Castle,
Llantwit Major,
South Glamorgan, U.K.

Jong, Dr. C.de
S.O.L. Chemie,
Archimedeslaan 16,
Utrecht, Netherlands.

Jong, Drs. O.de
Osterlaan 51,
Driebergen-Rijsenburg, Netherlands.

Jongejan, Drs. E.
Smelenhof. 25,
Milsbeek, Netherlands.

Kalu, Miss E.E.N.
State Schools Management Board,
Owerri, Imo State, Nigeria.

Kanter, Ir. J.de
Groenewoudseweg 24,
Nijmegen, Netherlands.

Kawakami Chikao,
1-4-3 Higashiogu,
Arakwater, Tokyo 153, Japan

Krasilchik, Dr. M.
Ceciap - c.p 11.324
S.Paulo, Brasil

Kenya, Mrs. M.
Graduate Studies Office,
Trinity College,
190 Pearse Street, Dublin 2 Ireland.

Kellington, Dr. S.H.
66 Dumgoyne Drive,
Bearsden, Glasgow U.K.

Kievit Drs. R.de
Mozartlaan 109,
Enschede, Netherlands.

King, W.K.
School of Education,
P.O. Box 64,
U.W.I. Bridgetown, Barbados.

Kitselaar, F.
B.v Heystl 14
Waalwijk, Netherlands.

Klosse, Dr. k.
Willingelaan 4,
Peize, Netherlands.

Kock, C. de
Hugo Verrieststraat 37
5044 RG Tilburg,
Netherlands.

Kole, Ir. A.P.
Philips Nederland,
Eindhoven, Netherlands.

Kooi, J.B. van der
De Eestukken 6
Haren (Gr), Netherlands.

Kramer, J.H.
Groenestein 29,
Roden, Netherlands.

Kroft, Drs. G.v.d.
Kerkstraat 49,
Giesbeek, Netherlands.

Kornhouser, Prof. A.
Dept of Chemistry,
University of Ljubljana,
Ljubljana, Yugoslavia.

Lambert, E.
c/o School of Education,
U.W.I. St Augustine, Trinidad, W.I.

Lemke, Prof. J.L.
City University of New York,
Brooklyn, N.Y. 11210, U.S.A.

Lewis, J.L.
Malvern College,
Malvern, Worcestershire, U.K.

Leijenaar, Drs. D.
Westersingel 34,
Groningen, Netherlands.

Liem, Dr. Tik.L.
St Francis Xavier University
Antigonish, Nova Scotia, Canada.

Linde, Drs. J.v.d.
Fred.Hendrikstraat 115,
Utrecht, Netherlands.

Lockard, Dr. J.D.
University of Maryland,
College Park, Maryland, 20742,
U.S.A.

Loh, K.S.
Jalan Swettenham,
Kuala Lumpur 10-02, Malaysia.

Loo, Mr. P.W.
Apartment Block 3, 65Q
Neptune Court,
Marine Vista, Singapore 15.

Lucas, Dr. A.M.
School of Education,
Flinders University,
Bedford Park,
South Australia, 5042.Australia.

Lutterodt, Dr. S.A.
Deptartment of Science Education,
University of Cape Coast,
Cape Coast, Ghana,

Maclay, R. de
Sydney Teachers College,
Box 63,
P.O. Camperdown 2050, N.S.W.
Australia.

MacGibbon, H.
Heinemann Educational Books,
48 Charles Street, London W1. U K.

Macmahon, C.
P.O. Box 422,
Lismore, N.S.W. Australia 2480

Malcolm, S,
11 Mills Place
LONDON W1 UK

Mani, T.C.
Ahmadu Bello University,
Zaria, Nigeria.

Manzell, Ms. S.
17 Southlands,
East Grinstead, Sussex U.K.

Manzelli, P.
Istituto Chimica Fisica,
Via G. Capponi no 9.
50121 Firenze, Italy.

Markering, Drs. S.G.C.
Allaburg 17-12
Wychen, Netherlands.

Marton-Lefevre, Ms. J.
I.C.S.U.
51 Blvd de Montmorency,
Paris 16, France.

Marshall, D.
25 Princess Gardens,
Acton, London W3, U.K.

Massey, N.B.
197 Water Street,
Cobourgh, Ontaria, Canada, K9A1E2

Matyas, Prof. M.
Institute of Solid State Physics,
Cuckrovarnicka 10
Prague 6, Czechoslovakia.

May, J.B.
Centre for Science Education,
Chelsea College,
Bridges Place, Fulham,
London SW6 UK.

Mendes, B.
Cx Postal 1170
13,100 Campinas SP, Brazil.

Merkus, Ir, R.
Lauwers 194,
Alphen A/D Rijn Netherlands.

Meijer, P.C.
Kon.Julianalaan 18
Slootdorp, Netherlands.

Minssen, Dr. M.
Institute for Science
Education (IPN)
Olshausenstrasse 40-60
D 2300 Kiel, Germany (FDR)

Mitchelmore, Dr. J.
Ministry of Education,
2 Caenwood Road, Kingston, Jamaica.

Morélis, Drs. H.
Odinkaveld 9
Delden, Netherlands

Mosala, P.
Department of Education,
Private Bag X0817
9870 Witzieshoek, South Africa.

Muralidhar, S.
University of South Pacific,
P.O. Box 1168, Suva, Fiji.

Ndu, L.O.
State School Management Board,
PMB 1160, Enugu, Nigeria.

Nezami, M.W.
Science Centre,
Ministry of Education, Kabul,
Afghanistan.

Nkambule, H.S.
P.O. Box 762,
Manzini,
Swaziland, Southern Africa.

Nwana, Prof, O.C.
Faculty of Education,
University of Nigeria,
Nsukka, Nigeria.

Nwosu, S.C.E.
Federal Ministry of Education,
1-3 Moloney Street,
Lagos, Nigeria.

Oyetola, O.A.
Federal Government College,
Ilorin, Nigeria.

Osiyale, Dr. A.O.
Faculty of Education,
University of Lagos,
Lagos, Nigeria.

Pantmann, J.
Valby Overdrev,
3200 Helsinge, Denmark

Parás, Mrs. E.
44 Carmen de Luna
BF Homes Paranque
Metro Manila, Philippines

Parás, F.
44 Carmen de Luna
BF Home Paranque,
Metro Manila, Philippines.

Parker, Mrs. S.
Department of Professional Studies,
The Polytechnic,
Bristol, U.K.

Pesaro, P.E.
Department of Isotope Research,
Weizmann Institute of Science,
Rehovot, Israel.

Pilgram, P.
SLO Postbus 2041
Enschede, Netherlands.

Pinnock. K.
John Murray Publishers,
50 Albermarle Street, London W1, U.K.

Pitre, B.G.
The Doon School,
Dehradun, India.

Pohlmann-Nepveu, J.
Hoofdweg 7,
Harkstede (Gr.), Netherlands.

Prabhakar, M.P.
Ministry of Education,
Kuala Lumpur, Malaysia.

Puri, O.M.P.
Clark College,
Atlanta, U.S.A.

Quiroz, Prof. C.A.
Coraceros 158,
Lima 21, Peru.

Quitzow, Dr. W.
Curtiusstrasse 45,
1000 Berlin 45, Germany

Raat, Dr. J.H.
Couperuslaan 1,
Uithoorn, Netherlands.

Ramirez-Villaseñor, Prof.C.R.
Centro de Investigación del I.P.N.
Apartado postal 19-197
Mexico 19 DF, Mexico.

Ramsey, Dr. G.A.
Torrens College of Advanced Education
Holbrooks Road,
Underdale 5032, Australia.

Raw, Prof. I.
City College,
Center for Biomedical Education,
New York 10031, U.S.A.

Reay, Miss J.F.
University of the West Indies
School of Education,
St. Augustine, Trinidad, W.I.

Reeves, J.
Institute of Education,
Ahmadu Bello University,
Zaria, Nigeria.

Richardson, R.P.
22 Blue Basin Gardens,
Diego Martin, Trinidad and Tobago,
W.I.

Richmond, P.E.
Department of Education,
The University, Southampton, U.K.

Rosier, Dr. M.
Australian Science Teachers
Association,
P.O. Box 210
Hawthorn, Victoria, 3122 Australia.

Rudstroom, Ms. R.
Division of Scientific Research
and Higher Education,
UNESCO, Paris 7e France.

Rundervoort, Drs. H.J.
Oosterkade 1-2
Amsterdam-1, Netherlands.

Rutherford, Dr. F.J.
National Science Foundation,
Washington D.C. 20550, U.S.A.

Rijst, Drs. J. van de
Dreef 107
3956 Es Leersum, Netherlands.

Ryan, J.O.
University College,
Galway, Ireland.

Saatveld, O.
Gyldendal Norst Forlag
Skolebokardelingen,
Universitetsgt.16, Oslo 1, Norway.

Sabar, Dr. N.
Tel-Aviv University,
Tel Aviv, Israel.

Santen, Drs. J.G.H.v.
Doesburgseweg 6,
Wehl, Netherlands.

Sawyerr, E.
Box 27,
Freetown, Sierra Leone.

Schaar, Drs. H.v.d.
Valeriusstraat 26 II,
Amsterdam, Netherlands.

Schipper, J.
Orinoco 3,
Amstelveen, Netherlands.

Schmidt, Prof. H.J.
Busc[illegible] 75,
D-4600 Dortmund 14 Germany, (FDR)

Schoen, Dr. A.M.
Nieuwe Achtergracht 166,
Amsterdam, Netherlands.

Scholte, Ir, H.G.M.
Jasmijnstraat 11,
Borne, Netherlands.

Schulkens, J.
Postbus 482
Den Bosch, Netherlands.

Selim, Prof.Dr. M.S.
109 Tahrer Street,
Dokki Square, Cairo, Egypt.

Showalter, V. Dr.
Centre for Unified Science,
Capital University,
Columbus, Ohio, 43209, U.S.A.

Shubber, K.E.
P.O. Box 348,
Manama, Bahrain.

Silber, R.
N.S.T.A.
1742 Connecticut Avenue NY
Washington DC 20009, U.S.A.

Silighem,

Belgium.

Singh, Prof. Chatar,
School of Physics,
Universiti Sains Malaysia, Penang,
Malaysia.

Situma, E.W.K.
University of East Anglia,
School of Chemical Science,
Norwich, U.K.

Slimming, D.
c/o British Council,
10 Spring Gardens, London SW1, U.K.

Sloan, D.
c/o British Council,
10 Spring Gardens, London SW1. U.K.

Smit, H.
Weerestein 8
Breukelen, Netherlands.

Smit-Miessen, Ms. Drs. M.M.
Toernooiveld,
Nijmegen, Netherlands.

Sood, Dr. J.K.
Regional College of Education,
Ajmer, India.

Souchon, J. Mme.
10 Rue Emile Morel,
92330 Sceavy, France.

Stevenson, J.
45 Closter Avenue,
Ashwood, 3147, Australia.

Summeren, P.v.
Doelstraat 24A.
Haarlem, Netherlands.

Tan Ir. B.L.
Tafelberg 20,
Dordrecht, Netherlands.

Taylor, Prof. C.A.
University College,
P.O. Box 78, Cardiff, U.K.

Taylor, G.
Heinemann Educational Ltd.
48 Charles Street, London W1, U.K.

Terp-Johansen,
Ordrup Have 12
2920 Charlottenlund, Denmark.

Teernstra, Dr. P.J.
Fideliolaan 108,
Amstelveen, Netherlands.

Tetsola, E.A.
Agbor Girls Grammar School,
Agbor, Nigeria.

Thomson, Dr. B.S.
2008 Beverly Road,
Columbus, Ohio, 43221 U.S.A.

Trommel, J.v.
Burg. Kruyffstraat 75,
Ridderkerk, Netherlands.

Turner, Dr. A.D.
Institute of Education,
20 Bedford Way, London WC1. U.K.

Toll, P.Y.M.
De Wieken 67,
Malden, Netherlands

Uppelschoten, Drs. H.
W. Heukelslaan 55,
Utrecht, Netherlands.

Uswyshyn, Dr.Evhan,
53 Arrowwood,
Winnipeg, Manitoba, Canada.

Vaernewijck, A.J.
Bosvogel 8
B-9210 Heusden, Belgium.

Veen, T.v.d.
Prinsengracht 468
Amsterdam, Netherlands.

Vegting, Drs. P.
University of Groningen,
Groningen, Netherlands.

Veje, Dr. C.J.
Tyborön Alle 22
DK-2720 Vanlöse, Denmark.

Ven, Drs. Ch.v.d.
Drentesingel 127
6835 HM Arnhem, Netherlands.

Velde, G.c.d.
Jan Gorislaan 130
3293 Kaggevinne, Belgium

Verbeke, M.M.
Universitaire Campus,
Kortrijk, Belgium.

Verkerk, G.
St. Hubertuslaan 10
Son en Breugel, Netherlands.

Vincentini Missoni Prof. M.
Université-Pz delle Scienze 5,
Rome, Italy.

Voorde, Dr. H. ten
Osnabrückstraat 7
Enschede, Netherlands.

Vos, Drs. W.de
Snellingerdijk 50
8431 EP Oosterwolde, Netherlands.

Wanchoo, Prof. V.
N.C.E.R.T.
Sri Aurobindo Marg,
New Delhi 110-016, India.

Werff-Woolhouse, Ms.S.M.
British Council,
Keizersgracht 343, Amsterdam,
Netherlands.

Williams, Dr. I.W.
Education Department,
University College of Swansea,
Swansea, U.K.

Winter, Mr. I.
8 Winston Avenue,
Seven Mile Beach, Tasmania,
Australia.

Wong, K.S.
Wa Wing Yung College,
Sheung Wo Street,
Homantin,
Kowloon, Hong Kong.

Xerri, C.J.
Education Office,
Lascaris, Valleta, Malta.

Yaxley, M.L.
c/o UNDP
P.O. Box 400, Kaduna, Nigeria.

Young, B.L.
c/o British Council,
Jakarta, Indonesia.

Zandstra, W.Y.
Parallelweg 25
7213 Gorssel, Netherlands.

Za'rour, Prof. Dr. G.I.
Science and Math. Education Center,
American University of Beirut,
Beirut, Lebanon.

Zozuvsky, R.
"Matal",
School of Education,
Tel Aviv University,
Tel Aviv, Israel.